PLANNING FOR LESS TRAVEL

IDENTIFYING LAND USE CHARACTERISTICS ASSOCIATED WITH MORE SUSTAINABLE TRAVEL PATTERNS

DOMINIC ST. JOHN STEAD

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at University College London

BARTLETT SCHOOL OF PLANNING AND ARCHITECTURE
UNIVERSITY COLLEGE LONDON

1999

ABSTRACT

This study examines the extent to which land use planning can influence travel and how it might be able to reduce the environmental impact of transport. Although other studies have examined this issue before, many have only examined the influence of a small number of land use characteristics and most have not taken account of socio-economic reasons for variations in travel in different areas. This study examines the influence of a range of land use characteristics on travel and takes into account a large number of socio-economic characteristics. It also examines whether the links between travel, socio-economic and land use characteristics have changed over time.

The hypothesis of the study is that *land use policies influence travel patterns even when differences in social and economic characteristics are taken into account.* The study examines several sets of data containing information on travel, socio-economic characteristics and land use. Data from the National Travel Survey are examined to identify relationships between land use, socio-economic characteristics and travel patterns. Data from four separate National Travel Surveys are used to examine whether these relationships change over time. Data from two local travel surveys from Kent and Leicestershire are also used to provide a more detailed level of analysis. The data from the two local surveys also allow some comparison with the data from the National Travel Surveys.

The relationships between land use, socio-economic characteristics and travel patterns are examined using multiple regression analysis. Although causal relationships cannot be identified in the absence of longitudinal data, the study does provide insights into possible interactions between land use, socio-economic characteristics and travel patterns. After identifying the land use characteristics associated with lower travel demand, the planning implications for reducing the demand for travel are considered. Issues of policy implementation including obstacles, barriers and responsibilities are discussed. The research contributes to knowledge about planning policies that promote more sustainable development. It focuses on a topic that might practically contribute to the search for indicators of sustainable development, the revision of government planning guidance on transport and land use planning and the formulation of the recently announced Urban White Paper. The research also identifies specific land use characteristics that might be used by local authorities in developing more sustainable planning policies.

The results of the study show that the variation in travel patterns across different areas is often due more to socio-economic reasons than land use characteristics. However, land use planning is still likely to have a significant effect on influencing travel patterns, particularly if supported by complementary measures.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to thank the following people for their help with this study:

David Banister for his inspiration and advice

Rachel for her love and understanding

Martin and *Steph* for their kindness

John Lee for producing the maps

James Shorten for helpful suggestions (occasionally about the thesis)

Paul Moore for statistical advice

Paige Mitchell for correcting my grammar

Paulo Câmara for arranging the interviews at Leicester City Council

Staff of *Leicester City Council* for giving their time for interviews

David Gillingwater for his comments on the results from Leicestershire

The *Engineering and Physical Science Research Council* for financial support

The *Data Archive, Kent County Council* and *Leicestershire County Council* for providing data for the research

Friends and *family* for being there

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Transport is one of the largest sources of environmental pollution. The large number of environmental impacts associated with transport range from local through to global. Transport now produces more than a fifth of the United Kingdom's emissions of carbon dioxide (contributing to global warming), it accounts for over a quarter of the United Kingdom's annual consumption of (mainly non-renewable) energy resources and produces more than a third of the United Kingdom's emissions of nitrogen oxides (with implications for acidification and poor air quality). Transport's contribution to environmental pollution is proportionally even larger in urban areas. Many of the environmental impacts associated with transport are becoming increasingly acute. Carbon dioxide emissions from transport are growing, transport energy consumption is increasing and air quality is worsening in both urban and rural areas.

A number of driving forces underlies these increasing environmental impacts. The movement of goods and people has increased. Freight transport has increased due to the growth in the volume of freight and the longer distances that goods are being carried. Much of the increase in passenger transport is due to journeys becoming longer, rather than more journeys being made. There has been a shift away from less environmentally damaging modes in both freight and passenger sectors. There have been large increases in road and air traffic for the transport of goods and people. Travel by foot and bicycle has fallen steeply over the last decade. The introduction of new technology has not been fast enough to stabilise many of the environmental impacts. Some of the reasons behind these travel trends include increases in car ownership and income, changes in the cost of travel, demographic and land use changes. Many of these factors are interconnected.

There is consensus that action must be taken to reduce the environmental impacts of transport. A variety of measures are available to reduce these impacts. These include fiscal policies, technology, education and regulation. All are important ways of reducing the environmental impacts of transport. Many of these measures may reinforce each other. Implementation of these measures relies on a number of agencies and several different levels of decision-making from the global level (as in the case of agreements on carbon dioxide emissions) down to the local level (local traffic targets for example).

There is some debate about the effectiveness of land use planning as a measure to reduce travel demand and the environmental impacts of transport. Various studies have demonstrated a link between land use characteristics and travel patterns which have led some to conclude that the differences in travel patterns are a direct consequence of land use planning. Others however have suggested that the observed variations in travel patterns in different areas are mainly due to economic and social reasons. The sceptics of land use planning measures rightly point out that different land uses are populated by different types of residents which means that some of the variation in travel patterns could be due to the characteristics of the residents, such as their employment type, age or income, rather than land use *per se*. Others still assert that both explanations may be valid and suggest that the various influences on travel demand may be interlinked. Some argue that land use planning has much potential to reduce travel demand, whilst others suggest that land use planning may not be as effective as other measures, such as economic instruments, in reducing travel demand.

1.2 THE FOCUS OF THE RESEARCH

This study is concerned with these debates particularly in terms of the extent to which land use planning can affect travel demand and the linkages between travel patterns, land use and socio-economic characteristics. The study is also concerned with the extent to which some of these linkages have changed over time.

The three main aims of the study are:

(i) to identify the extent to which land use characteristics influence travel

(ii) to identify the extent to which socio-economic characteristics are also likely to influence travel

(iii) to explore the interactions between travel patterns, land use and socio-economic characteristics

Seven research objectives have been identified that will lead towards the achievement of the study aims. These are:

(i) to identify the effects of transport on sustainable development particularly on the environment

(ii) to review and assess other empirical research on the land use transport interaction

(iii) to examine land use planning in the United Kingdom (particularly in England and Wales) and the extent to which transport and land use decisions are currently integrated

(iv) to investigate the relationships between transport emissions, energy consumption and various measures of travel patterns and to determine whether the emissions of different pollutants follow similar trends and whether they might be represented by one or more indicators of travel patterns

(v) to analyse data from national and local sources and examine static and temporal interactions between land use, socio-economic characteristics and travel

(vi) to compare and synthesise the results from the analyses of national and local data sources and to identify the key socio-economic and land use characteristics associated with less travel

(vii) to identify obstacles, barriers and responsibilities associated with the introduction of more sustainable planning policies

The hypothesis of the study is that *land use policies influence travel patterns even when differences in social and economic characteristics are taken into account.* The different types of land use characteristics examined in this study are ones which are influenced by planning policy. These include population density, settlement size, proximity to public transport, the mixing of land uses, proximity to local facilities and the proximity to the main transport network. The conceptual framework of this study supposes that travel patterns are the consequence of interlinkages between a range of social, economic, demographic factors (collectively called socio-economic characteristics in this study) and land use characteristics.

Seven secondary research hypotheses are tested in the study:

(i) average travel distance per person decreases as the distance to the urban centre decreases

(ii) average travel distance per person decreases as settlement size increases

(iii) average travel distance per person decreases as the proximity to local facilities increases

(iv) average travel distance per person decreases as the density of development increases

(v) average travel distance per person is lower where land uses are more mixed

(vi) average travel distance per person is lower where residential parking is limited

(vii) average travel distance per person increases as the proximity to the main transport network (road and rail) increases

1.3 Main Land use Characteristics examined in the Study

The rationale for each of these secondary research hypotheses is outlined in turn.

1.3.1 Distance to the Urban Centre

The proximity to the urban centre is likely to influence travel distance since many jobs and services are in urban areas. It is likely that travel distance increases as the distance to the nearest urban centre increases. Very high distances from urban centres may also influence the frequency of journeys, particularly for more discretionary journeys (such as social or entertainment purposes). The overall result of these effects in terms of travel distance per person is not clear. The hypothesis is that average travel distance per person decreases as the distance to the urban centre decreases. Five categories of proximity to the urban centre are used. These are based on the time to walk to the nearest high street shops.

1.3.2 Settlement Size

Settlement size may affect the range of local jobs and services that can be supported and may influence the range of public transport services which can be provided. Thus small settlements that are unable to support a large range of services and facilities may force local residents to travel longer distances in order to access the services and facilities that they require. Very large, centralised settlements may on the other hand lead to longer travel distances as the separation between homes and the urban centre increases. Large settlements with a wide range of jobs and services may also attract people living long distances away to travel to them. The hypothesis is that average travel distance per person decreases as settlement size increases. The measures of settlement size used in this study are based on the measures recorded in the National Travel Survey.

1.3.3 The Mixing of Land Uses

The mixing of land uses may affect the physical separation of activities and therefore influence travel demand. The more mixed the land use, the greater the opportunity of activities and services within the immediate area. The hypothesis is that average travel distance per person is lower where land uses are more mixed. The mixing of land uses is measured using ward-level job ratio. This is the ratio of the number of persons employed to the number of residents available for work in the ward. It indicates the availability of local employment and to some extent the availability of local facilities (since local facilities add to the number of local jobs). Three categories of job ratio are examined: low job ratio (less than 0.5, which means that there are more economically active residents than jobs); balanced job ratio (between 0.5 and 1.0, which means that there are similar numbers of economically active residents and jobs); high job ratio (above 1.5, which means that there are more jobs than economically active residents).

1.3.4 The Provision of Local Facilities

The provision of local facilities and services may clearly reduce travel distance. The hypothesis is that average travel distance per person decreases as the proximity to public transport increases. A single measure containing three categories of the proximity to local facilities is used. The first is a highly accessible category in which the nearest chemist, post office and grocers are all within a 6-minute walk from home. The second category describes average proximity to local facilities where the nearest chemist, post office and grocers are all within a 44-minute walk from home. The third category with the lowest proximity to local facilities applies to locations where the nearest chemist, post office and grocers are all further than a 44-minute walk from home. These categories are derived from the measures recorded in the National Travel Surveys.

1.3.5 The Density of Development

Population density may be linked to travel patterns for several reasons. Firstly higher population densities widen the range of opportunities for the development of local personal contacts and activities that can be maintained without resort to motorised travel. Secondly higher densities widen the range of services that can be supported in the local area and reduce the need to travel long distances. Thirdly higher density patterns of development tend to reduce average distances between homes, services, employment and other opportunities which reduces travel distance. Fourthly high densities may be more amenable to public transport operation and use and less amenable to car ownership and use, which have implications to modal choice. The hypothesis is travel distance per person decreases as population density increases. The effect of population density on travel distance is examined at two different scales – at the local authority scale and the ward scale. Measures of population are expressed as gross densities – the number of people or workers divided by the total area (including the area of houses, gardens, roads, schools, parks and so on).

1.3.6 Proximity to Main Transport Networks

The proximity to main transport (road and rail) networks may also influence travel patterns and consequently travel distance. Better access to major transport networks, particularly road and rail networks, increases travel speeds and extends the distance which can be covered in a fixed time. Major transport networks can be a powerful influence on the dispersal of both residential and employment development. The proximity to main road and rail networks may lead to travel patterns characterised by long travel distances. The hypothesis is that average travel distance per person decreases as the proximity to the main road and rail network increases. Simple measures of proximity to main road and rail networks are used. Wards are either classified as close or not close to road or rail networks. Wards containing a motorway or main railway station are classified as close to the road or rail network. Other wards are classified as not being close to the road or rail network.

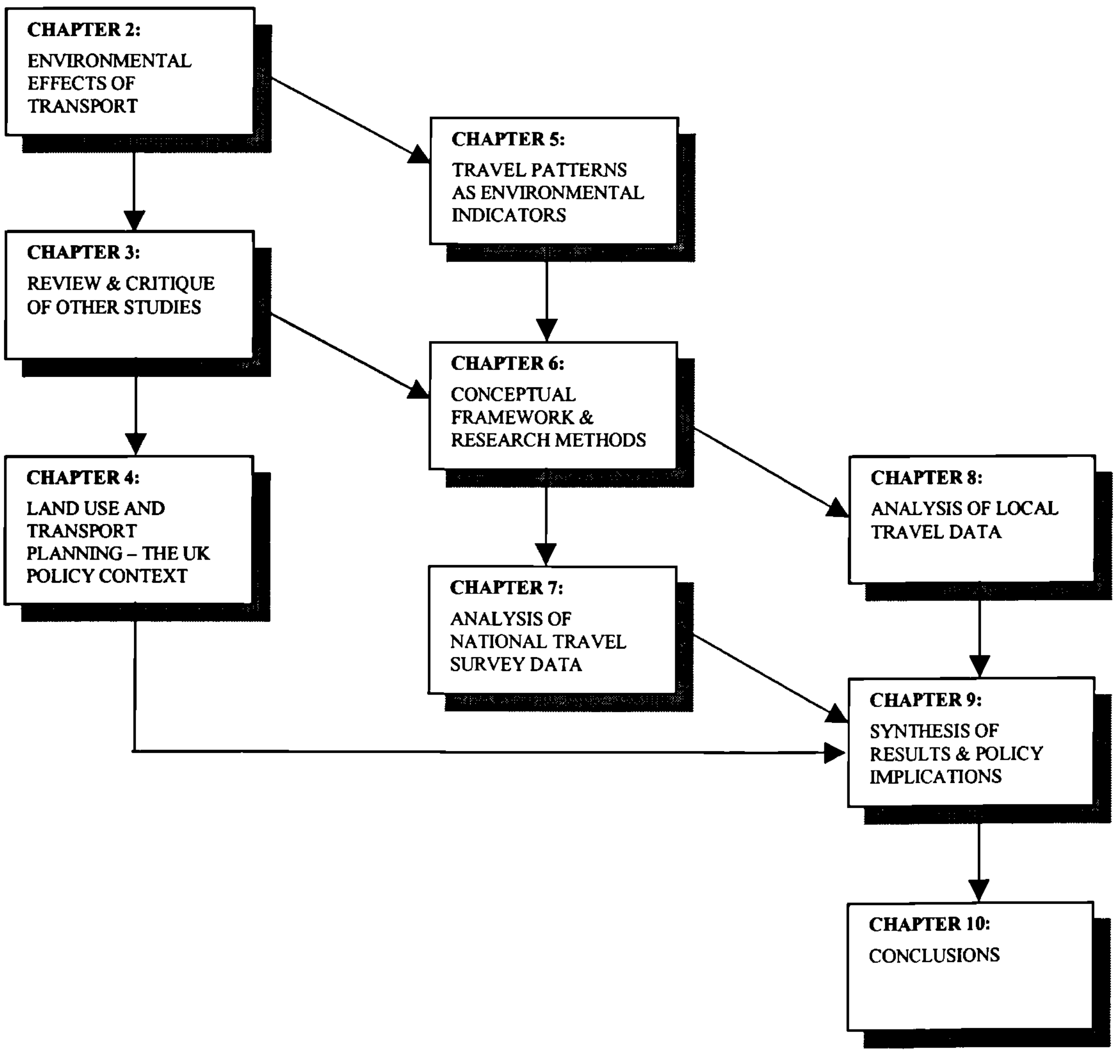
1.3.7 The Availability of Residential Parking

Limited residential parking may discourage car ownership and use, particularly if finding a parking space close to home is difficult. It may also have the effect of encouraging trip chaining, rather than several journeys starting or ending at home and encouraging local journeys by non-motorised modes especially where there is the prospect of a long search for parking. The hypothesis is that average travel distance per person is lower where there residential parking is limited. A simple measure of the availability of residential parking is used. Wards where residential parking schemes have been introduced are classified as having limited parking. This assumes that residential parking schemes reflect the areas of limited availability and highest demand for parking which is usually the case for the implementation of such schemes. Wards where no residential parking schemes have been introduced are classified as not having limited parking.

1.4 THE STRUCTURE OF THE STUDY

The study is divided into ten chapters. The structure of the report is based on the seven research objectives (section 1.2). The effect of transport on the environment is examined in chapter 2. Some of the driving forces behind the environmental trends are discussed. The range of different measures available to address the environmental impacts of transport is reviewed. Chapter 3 reviews recent literature concerning the relationships between land use and travel patterns. Evidence for interlinkage between social, economic, demographic, land use characteristics and travel patterns is also reviewed and a critique of the evidence is presented. The national policy context for land use planning and transport planning is examined in chapter 4. This includes examination of the policy and organisational changes in relation to land use and transport planning and the driving forces behind these changes. Current planning policy guidance relating to the issues of population density, settlement size, the proximity to public transport, the proximity to local facilities, the proximity to the main road network and the mixing of land uses are identified. Chapter 5 explores the relationship between transport emissions, energy consumption and various measures of travel patterns and examines whether the emissions of different pollutants follow similar trends and whether they can be represented by one or more indicators of travel patterns. The conceptual framework and study methods are presented in chapter 6 and are based on the review and critique of other empirical studies (presented in chapter 3). Chapter 7 reports on the analyses of data sets from four consecutive United Kingdom National Travel Surveys (carried out in 1978/79, 1985/86, 1989/91 and 1991/93). The chapter examines the effect of land use and socio-economic characteristics on travel distance and identifies key socio-economic predictors of travel distance. The changes in these relationships over time are considered. The effects of land use and socio-economic characteristics on travel distance in Kent and Leicestershire are then examined in chapter 8. The analysis of data from Kent and Leicestershire allows comparison with the results from the National Travel Survey data and allows other land use characteristics to be examined that were not recorded in the National Travel Survey data. Chapter 9 contains a synthesis of the results of chapters 7 and 8. The implications for reducing the environmental impacts of transport through land use planning are discussed in relation to current government policy planning guidance. The relative importance of land use and socio-economic characteristics in explaining the variation in travel patterns are discussed. The chapter then identifies policies that might promote land use characteristics associated with less travel. Issues of implementation including obstacles and barriers are considered. The conclusions of the study are presented in chapter 10. The structure of the report is summarised in Figure 1.1.

FIGURE 1.1 THE STRUCTURE OF THE STUDY



CHAPTER 2: ENVIRONMENTAL EFFECTS OF TRANSPORT

Transport is one of the largest sources of environmental pollution. The large number of significant environmental impacts associated with transport range from local through to global and cut across a large range of issues including air quality, energy use, waste production and health (Table 2.1). Many of these impacts are increasing. Others are beginning to decrease but these impacts may start to increase again in the longer term unless action is taken to reduce transport growth. Transport is also associated with a number of adverse social and economic impacts although these impacts are not the main focus of this study.

2.1 THE IMPACTS

Transport is associated with a wide range of environmental impacts. These comprise energy and mineral resources, land resources, water resources, air quality, solid waste, biodiversity, noise and vibration, built environment impacts and health effects. Impacts across these nine categories are outlined below.

2.1.1 Energy and Mineral Resources

Transport currently accounts for almost one third of United Kingdom energy consumption. More than 40 million tonnes of oil were consumed by the transport sector in 1995 (Department of Trade and Industry, 1997). The transport sector is now the largest and fastest increasing consumer of energy due mainly to the growth in road and air transport. The last decade saw large increases in the use of energy intensive modes such as cars and aircraft for the movement of passengers and freight. Over the same period there was a decrease in the use of use energy efficient modes such as walking and cycling. Passenger vehicles became more fuel efficient but factors such as catalytic converters, higher safety standards, air conditioning and higher vehicle performance tended to counter the fuel efficiency gains from improved engine design. In other sectors of energy consumption, domestic energy use remained relatively constant over the last decade and energy use in the industrial sector fell.

TABLE 2.1 THE ENVIRONMENTAL IMPACTS OF TRANSPORT IN THE UNITED KINGDOM

Environmental media	*Environmental impacts*	*Transport's contribution (1995 unless otherwise stated)*
Energy and mineral resources	• Energy resources used for transport (mainly oil-based) • Extraction of infrastructure construction materials	• 44.8 million tonnes of petroleum consumed by transport • transport accounts for approximately one-third of the UK's total energy consumption • approximately 120,000 tonnes of aggregates per kilometre of 3-lane motorway • 78 million tonnes of roadstone extracted
Land resources	• Land used for infrastructure.	• approximately 4.2 hectares of land per kilometre of 3-lane motorway • 1,725 hectares of rural land developed for transport and utilities per annum (1992)
Water resources	• Surface and groundwater pollution by surface run-off • Changes to water systems by infrastructure construction • Pollution from oil spillage	• 25 per cent of water pollution incidents in England and Wales caused by oil • 585 oil spills reported in the UK • 142 oil spills requiring clean-up in the UK
Air quality	• Global pollutants (such as carbon dioxide) • Local pollutants (such as carbon monoxide, nitrogen oxides, particulate matter, volatile organic compounds)	• 25 per cent of the UK's carbon dioxide emissions (CO_2) • 76 per cent of the UK's emissions of carbon monoxide (CO) • 56 per cent of the UK's emissions of nitrogen oxides (NO_X) • 51 per cent of the UK's emissions of black smoke (particulates) • 40 per cent of UK emissions of volatile organic compounds (VOCs)
Solid waste	• Scrapped vehicles • Waste oil and tyres	• approximately 1.5 million vehicles scrapped • more than 40 million scrap tyres
Biodiversity	• Partition or destruction of wildlife habitats from infrastructure construction	
Noise and vibration	• Noise and vibration near main roads, railway lines and airports	• approximately 3,500 complaints about noise from road traffic • approximately 6,500 complaints about noise from air traffic
Built environment	• Structural damage to infrastructure (e.g. road surfaces, bridges) • Property damage from accidents • Building corrosion from local pollutants	• more than £1.5 million annual road damage costs
Health	• Deaths and injuries from accidents • Noise disturbance • Illness and premature death from local pollutants	• 3,500 deaths • 44,000 serious injuries • 49 per cent of people who can hear noise from aircraft or trains consider it a nuisance (1991) • 63 per cent of people who can hear noise from road traffic consider it a nuisance (1991) • between 12,000 and 24,000 premature deaths due to air pollution • between 14,000 and 24,000 hospital admissions and re-admissions may be associated with air pollution

Sources: Banister (1998a); Central Statistical Office (1997); Committee on the Medical Effects of Air Pollutants (1998); Department of the Environment, Transport and the Regions (1997a, b and c); Department of Trade and Industry (1997); Maddison et al (1995); OECD (1988) and Royal Commission on Environmental Pollution (1994).

In 1995, 78 million tonnes of roadstone were quarried in the United Kingdom, almost one-third more than the tonnage quarried in 1985 (Central Statistical Office, 1997). According to the Royal Commission on Environmental Pollution (1994) the construction of one kilometre of a three-lane motorway requires around 120,000 tonnes of aggregates. The extraction of aggregates and roadstone can damage natural habitats, scar the landscape and can also create noise and disturbance from quarrying and the transport of materials. In the South-East of England, where demand for aggregates is greatest, only approximately half of the region's requirements come from the region. The remainder is transported to the South-East from other regions (mainly the South-West and the East Midlands regions) which adds to long distance freight movement (Royal Commission on Environmental Pollution, 1994). Industrial or demolition waste could be used for certain road building and maintenance purposes to reduce the demand for quarried materials although only a small proportion of materials are currently used in the United Kingdom because of restrictive specifications in road construction and maintenance contracts and the relatively low cost of quarried materials (ibid.).

2.1.2 Land Resources

Transport occupies substantial areas of land and the amount of land used for transport infrastructure currently amounts to around 2,500 hectares per year (equivalent in area to a square whose sides measure five kilometres). Roads occupy approximately one-fifth of the urban surface area and railways take up around a further four per cent of the surface of large cities (ibid.). In 1990, roads occupied 3.3 per cent of the total land area of Britain: 1.4 per cent of which were within built-up areas and 1.9 per cent outside built-up areas (ibid.). Approximately 12 per cent of all land developed in 1992 was for the construction of transport and utilities infrastructure (2,685 hectares of land). More than half of this land (1,540 hectares) was previously used for agricultural purposes (Department of the Environment, Transport and the Regions, 1997a). Every kilometre of three-lane motorway requires 4.2 hectares of land (Banister, 1998a). In addition to the land consumed for roads, significant amounts are also used for the storage of vehicles. The effects of this land loss include the loss of productive agricultural areas, the loss of biodiversity and the fragmentation and severance of local communities (see below).

2.1.3 Water Resources

Transport accounts for approximately three-quarters of the consumption of petroleum products in the United Kingdom (Department of Trade and Industry, 1997). As such, transport must bear a large part of the responsibility for the 585 oil spills in United Kingdom coastal and marine waters in 1995. Of these spills, 95 released in excess of 100 gallons and 142 required clean-up action (Department of the Environment, Transport and the Regions, 1997c). In addition, more than a quarter of the 23,463 inland water pollution incidents in England and Wales in 1995 were caused by oil (Department of the Environment, Transport and the Regions, 1997c), some of these arising from the spillage of oil from transport. The oil spill from the Sea Empress in February 1996 off the coast of Milford Haven is a recent example of a major of water pollution incident with serious impacts on biodiversity, recreation and tourism. 72,000 tonnes of crude oil were released into the sea, of which between 3,000 and 5,000 tonnes reached the shore, affecting 200 kilometres of shoreline (Maritime and Coastguard Agency, 1997).

2.1.4 Air quality

Transport produces a number of emissions that are detrimental to air quality. These include global pollutants (such as carbon dioxide which contributes to global warming), national or regional pollutants (nitrogen oxides which produces acidification or 'acid rain' for example) and local pollutants (such as particulates which contribute to respiratory problems including the increased susceptibility to asthma). Transport's contribution to environmental pollution in urban areas is particularly large, where transport is by far the most significant contributor of most emissions. The temporal trends in air pollutants from transport are mixed. Some emissions continue to increase, others are beginning to fall. However, some of the emissions that are decreasing may be a problem in the future if the growth in transport increases faster than improvements in technology (see for example Howard, 1990; Department of the Environment, Transport and the Regions, 1997d).

Carbon dioxide is mainly caused by the combustion of fuels. It is the most important greenhouse gas and is responsible for global warming and climate change. Transport now accounts for approximately one quarter of United Kingdom carbon dioxide emissions, most of which comes from road transport. Emissions of carbon dioxide from road transport increased by 23 per cent between 1985 and 1995 and by 21 per cent from non-road transport. On the basis of current projections carbon dioxide emissions from the transport sector look set to continue increasing over the next 20 years (Department of Trade and Industry, 1995). At the European level a 40 per cent increase in carbon dioxide emissions from transport might be expected between 1995 and 2010 if existing trends continue (Commission of the European Communities, 1998).

Nitrogen oxides cause national and transnational pollution, contributing to acid deposition and, in combination with ozone, the formation of secondary pollutants, which give rise to photochemical smog and poor air quality. More than half of all emissions of nitrogen oxides originates from road transport. Emissions of nitrogen oxides from the transport experienced a rapid increase up to 1989, followed by a steady decrease, due mainly to the introduction of catalytic converters. Emissions of nitrogen oxides are expected to continue to decrease beyond 2000 but are likely to begin increasing again between 2000 and 2010 as increasing levels of traffic outweigh the emission reductions achieved by catalytic converters (Department of the Environment, Transport and the Regions, 1997d).

Carbon monoxide indirectly contributes to the greenhouse effect. It is also responsible for health problems, particularly in urban areas, where it can exacerbate cardiovascular disease and, in combination with other pollutants, contribute to respiratory conditions (Barde and Button, 1990). More than three-quarters of all carbon monoxide emissions are produced by transport. Emissions of carbon monoxide follow very similar trends as emissions of nitrogen oxides. Emissions of carbon monoxide from the transport experienced a rapid increase up to 1989, followed by a steady decrease, due mainly to the introduction of catalytic converters. As with emissions of nitrogen oxides, emissions of carbon monoxide are expected to continue to decrease beyond 2000 but are likely to begin increasing again between 2000 and 2010 as increasing levels of traffic outweigh the emission reductions achieved by catalytic converters (Department of the Environment, Transport and the Regions, 1997d).

Particulates consist of mainly carbon and unburned or partially burned organic compounds. Airborne particulate matter is the primary cause of the soiling of buildings and visibility loss on hazy days. The medical impacts associated with particulates include respiratory problems such as the increased susceptibility to asthma (Royal Commission on Environmental

Pollution, 1994). Recent research indicates that there is no safe limit for particulate pollution[1] (Department of the Environment, 1997a). Whereas the domestic sector was the largest source of emissions of particulates a decade ago, more than half of the United Kingdom's emissions of particulates now originate from transport, particularly from diesel vehicles (Department of the Environment, Transport and the Regions, 1997d). Emissions of black smoke from transport increased up to 1992, from which time emissions have declined due to the introduction of less polluting diesel. As with emissions of nitrogen oxides, emissions of particulates are expected to continue to decrease beyond 2000 but may begin to increase again in the longer term as increasing levels of traffic outweigh the emission reductions achieved by the use of less polluting fuel (Department of the Environment, Transport and the Regions, 1997d). Thus technology can assist in reducing pollutants such as nitrogen oxides, carbon monoxide and particulates in the short to medium term but other solutions are needed to address the longer-term problems.

2.1.5 Solid waste

Transport accounts for a significant proportion of solid waste due to the high rate of vehicle scrappage. Approximately 1.5 million road vehicles are scrapped annually (Department of the Environment, Transport and the Regions, 1997b), resulting in approximately half a million tonnes of material for landfill after recycling and reclamation (Royal Commission on Environmental Pollution, 1994). Vehicle residues for landfill are expected to double this decade as the proportion of steel used in vehicles declines (ibid.). Plastics are increasingly being used in vehicle manufacture but few of these are recycled at present. The content of plastics in vehicles is expected to increase twofold between 1990 and 2000 (ibid.). Waste tyres present another major solid waste problem: more than 40 million tyres are scrapped each year, many of which are landfilled or illegally dumped (ibid.). Tyre dumps may catch fire and are then extremely difficult and expensive to extinguish. As well as causing problems of air pollution, tyre fires produce highly polluting leachate which may have serious consequences for groundwater pollution (ibid.).

1. The research relates to particulates under 10 microns in size (PM_{10}).

2.1.6 Biodiversity

Infrastructure construction and maintenance often leads to losses of vegetation-rich land including hedgerows and verges. Newly planted verges are generally not an adequate replacement (ibid.). Where new infrastructure cuts across natural or semi-natural habitat, the effects on biodiversity will depend on factors such as the habitat's sensitivity, the siting of the infrastructure and the area of land used for construction. Transport infrastructure such as roads, airports or railways may act as a barrier to the movement of species which may result in the separation of populations and a decline in numbers. Rarer species may disappear if the population becomes too small. Sites of national and international conservation importance are protected from development under various designations (Sites of Special Scientific Interest, Special Protection Areas, Ramsar sites for example) although absolute protection from development is not guaranteed. The M3 extension through Twyford Down is one example of a recent infrastructure project affecting important conservation areas. Development took place in an Area of Outstanding Natural Beauty and affected two Sites of Special Scientific Interest and three ancient monuments (ibid.).

2.1.7 Noise and vibration

Transport is the most pervasive source of noise for most people in the United Kingdom. The most common sources of transport noise (in order of importance) are road traffic, aircraft and trains. Road traffic is generally considered to be more of a nuisance than most other sources of noise (Department of the Environment, Transport and the Regions, 1997c). Complaints about noise have substantially increased over the last decade. In England and Wales, complaints about road traffic have increased by almost one third between 1984/85 and 1994/95, whilst complaints about aircraft have increased more than seven-fold. There are now approximately 3,500 complaints about noise from road traffic in the United Kingdom and approximately 6,500 complaints about noise from aircraft (Department of the Environment, Transport and the Regions, 1997c). Conclusive evidence of the health effects of noise is limited to cases of hearing loss and tinnitus caused by long periods of exposure to high noise levels – more than 75-80 dB(A) (Royal Commission on Environmental Pollution, 1994). It is unlikely that most people are exposed to traffic noise at these levels over a sufficiently long period to cause these health effects, although traffic noise may aggravate or contribute to stress-related health problems such as raised blood pressure and minor psychiatric illness

(Taylor and Watkins, 1987; OECD, 1991). Sleep is also disturbed by transport noise for a number of people (Jones, 1990). Transport movement also causes vibration which may be another contributory factor to stress-related diseases (Royal Commission on Environmental Pollution, 1994). Excessive noise from traffic may also discourage social interaction in streets and reduce the attractiveness of walking or cycling.

2.1.8 Built Environment

Transport's impact on the built environment includes the damage to property as a result of accidents, structural damage to transport infrastructure (such as road surfaces and bridges) and damage to property and monuments as a consequence of corrosive local pollutants. Road damage is dependent on factors such as climate, the road surface and the axle weight of vehicles using the road. Because road damage is related exponentially with axle weight, heavy vehicles with few axles cause most of the damage. Maddison et al (1995) report that the annual road damage costs in the United Kingdom are in excess of £1.5 million.

2.1.9 Health

Nearly two-fifths of accidental deaths in Britain are caused by transport. Transport accounts for more than 10 deaths and 15 serious injuries in Britain every day (Department of the Environment, Transport and the Regions, 1997b). Although the trends in transport-related deaths and serious injuries are falling, the magnitude of the problem is still serious, particularly for pedestrians and cyclists. The rate of child pedestrian deaths is higher in England and Wales than in New Zealand, the USA, Denmark or Sweden (Roberts, 1993). Recent research suggests that the deaths of between 12,000 and 24,000 vulnerable people may be brought forward in Britain each year and between 14,000 and 24,000 hospital admissions and re-admissions per annum may arise as a result of short term air pollution containing ozone, sulphur dioxide or particulates (Committee on the Medical Effects of Air Pollutants, 1998). Transport is a major contributor to pollutants that form ozone as a secondary pollutant (such as nitric oxide) and the largest source of particulate matter (see section 2.1.4). The people most likely to be affected by air pollution are likely to belong to vulnerable groups such as pregnant women, the frail or the very ill. Air pollution levels normally experienced in the United Kingdom are unlikely to have any short-term effects on other groups, although the long-term effects are still unknown.

2.1.10 Other

Heavy traffic disrupts home and community life. Research by Appleyard and Lintell (1969) showed that social contact on the street declines as traffic volumes increase. Behavioural differences such as use of front gardens and front rooms in homes were correlated with traffic volumes. Many families chose to move away from heavily trafficked areas if they could afford to do so. Transport corridors (a motorway or railway line for example) can cause the partition or destruction of neighbourhoods. Social contact and/or walk journeys may be inhibited where corridors are difficult or inconvenient to cross.

2.2 The Travel Trends Contributing To These Impacts

Having identified some of the main environmental impacts of transport, this section examines the trends in travel patterns that underlie these impacts. Evidence from National Travel Survey data shows that the average annual distance travelled per person in 1994/96 was around 6,500 miles: 23 per cent more than the average travel distance just a decade earlier (1985/86). The increase in travel distance was the consequence of longer journeys rather than more journeys. The frequency of journeys increased by 3 per cent between 1985/86 and 1994/96, whilst the average journey length increased by 19 per cent. Current traffic projections suggest that traffic could grow by one-third over the next 20 years and by more than a half on trunk roads in the absence of policy changes (Department of the Environment, Transport and the Regions, 1998a). Some of the main changes in the journey frequency, length and total distance of different transport modes and journey purposes are discussed below.

2.2.1 Transport Mode

The main transport modes that account for much of the annual distance travelled per person (in order of importance) are car, bus (including coach), rail (including underground) and foot (Table 2.2). The last decade saw large increases in distance travelled by the car and decreases in distance by foot, cycle, motorcycle and bus.

TABLE 2.2 TRAVEL TRENDS BY TRANSPORT MODE BETWEEN 1985/86 AND 1994/96

Transport mode	*Journey Frequency (trips / person / year)*			*Average Journey Length (miles)*			*Total Distance Travelled (miles / person / year)*		
	85/86	*94/96*	*% change*	*85/86*	*94/96*	*% change*	*85/86*	*94/96*	*% change*
walk	350	303	-13%	0.6	0.6	0%	210	182	-13%
bicycle	25	17	-32%	1.8	2.2	22%	45	37	-17%
car	517	631	22%	7.8	8.5	9%	4,009	5,347	33%
motorcycle	9	4	-56%	5.8	7.6	31%	52	30	-42%
other private	14	8	-43%	12.2	15.2	25%	171	122	-29%
local bus	83	65	-22%	3.7	4.0	10%	304	263	-14%
other bus	2	2	0%	72.2	59.5	-18%	144	119	-18%
London underground	6	6	0%	7.8	8.2	5%	47	49	5%
British Rail	12	10	-17%	28.1	33.2	18%	337	332	-2%
taxi/minicab	7	10	43%	4.1	3.7	-10%	29	37	29%
other public	1	1	0%	18.6	49.8	168%	19	50	168%
All modes	1,024	1,057	3%	5.2	6.2	19%	5,325	6,553	23%

Source: Department of the Environment, Transport and the Regions (1997e). Data includes journeys under 1 mile.

The car accounts for more than 80 per cent of all distance travelled by passengers in Britain. The average total distance travelled per person per year by car is over 5,000 miles – a third more than the previous decade and more than double the figure for two decades ago. The car now accounts for almost 60 per cent of all journeys (including journeys under 1 mile).

Journeys by local bus decreased by over 20 per cent between 1985/86 and 1994/96, whilst the average journey length by local bus increased. Bus travel now accounts for 6 per cent of all journeys compared to 8 per cent a decade earlier and 12 per cent two decades ago. The number of rail journeys declined by 17 per cent between 1985/86 and 1994/96, whilst the average journey length by rail increased by 18 per cent. The average journey distance by rail is around 33 miles. Rail travel accounts for less than 2 per cent of all journeys but more than 5 per cent of travel distance.

Journeys by foot account for more than a quarter of all journeys but only 3 per cent of all travel distance since journeys by foot are usually short (just over half a mile on average). The frequency of journeys by foot decreased by 13 per cent between 1985/86 and 1994/96, whilst the average journey length remained constant. Even short journeys under 2 miles are now often undertaken by car rather than by foot or bicycle. There has been a large fall (by almost a third) in the number of cycling journeys over the last decade. Journeys by bicycle are on average just over 2 miles in length.

2.2.2 Journey Purpose

The main journey purposes that account for much of the annual distance travelled per person (in order of importance) are social purposes (visiting friends, entertainment), commuting, recreation (sport, holidays, day trips), shopping and business purposes (Table 2.3). These five journey purposes account for over 80 per cent of the distance travelled per person. All of these purposes have experienced increases in distance over the last decade.

TABLE 2.3 TRAVEL TRENDS BY JOURNEY PURPOSE BETWEEN 1985/86 AND 1994/96

Journey purpose	*Journey frequency (trips / person / year)*			*Average journey length (miles)*			*Total distance travelled (miles / person / year)*		
	85/86	*94/96*	*% change*	*85/86*	*94/96*	*% change*	*85/86*	*94/96*	*% change*
Commuting	150	140	-7%	7.2	9.0	26%	1,075	1,265	18%
Business	27	33	22%	20.1	21.1	5%	543	696	28%
Education	39	38	-3%	3.8	4.5	20%	147	172	17%
Escort education	13	22	69%	2.9	3.5	20%	38	77	103%
Shopping	125	148	18%	4.6	5.2	14%	577	776	34%
Other escort	56	68	21%	5.5	5.8	4%	309	391	27%
Other personal business	59	71	20%	5.3	6.0	13%	315	428	36%
Visit friends at home	104	108	4%	9.1	10.5	15%	945	1,132	20%
Visit friends elsewhere	33	30	-9%	6.1	6.9	14%	200	208	4%
Entertainment	30	30	0%	8.0	9.8	22%	241	294	22%
Sport	16	20	25%	6.9	6.7	-3%	110	133	21%
Holiday	7	9	29%	48.0	53.2	11%	336	479	43%
Day trip	16	20	25%	19.2	18.3	-5%	307	365	19%
Other	15	14	-7%	3.1	2.6	-18%	47	36	-23%
All purposes	689	753	9%	7.5	8.6	14%	5,190	6,454	24%

Source: Department of the Environment, Transport and the Regions, 1997e. Data excludes journeys under 1 mile.

In 1994/96, social journeys accounted for over a fifth of all journeys and over a quarter of all distance travelled. The 20 per cent increase in distance travelled for social purposes over the last decade has been mainly due to the increase in journey length rather than increases in journey frequency. Journeys to visit friends account for a large proportion (over 80 per cent) of social journeys.

Commuting journeys accounted for 19 per cent of all journeys in 1994/96. The average frequency of commuting journeys decreased between 1985/86 and 1994/96 due to changes in the proportion of the population in employment and other factors such as increases in part-time work and the number of people working at home. The average length of commuting journeys on the other hand increased by more than a quarter between 1985/86 and 1994/96, leading to an overall increase of 18 per cent in total distance travelled for commuting.

Recreation journeys (sport, holidays, day trips) account for fewer than 7 per cent of all journeys but more than 15 per cent of the total distance travelled due to the long distances of these journeys, especially holiday journeys which are over 53 miles on average. Holiday travel distance increased by over 40 per cent between 1985/86 and 1994/96 due to some extent to increases in journey length but mainly due to increases in journey frequency.

Shopping journeys account for more than 20 per cent of all journeys. The frequency of these journeys has increased by 18 per cent over the last decade and the average distance has increased at a similar rate which amounts to a 34 per cent increase in the total distance travelled for shopping purposes between 1985/86 and 1994/96. The average length of a shopping journey is just over 5 miles. Shopping journeys account for 12 per cent of total distance travelled.

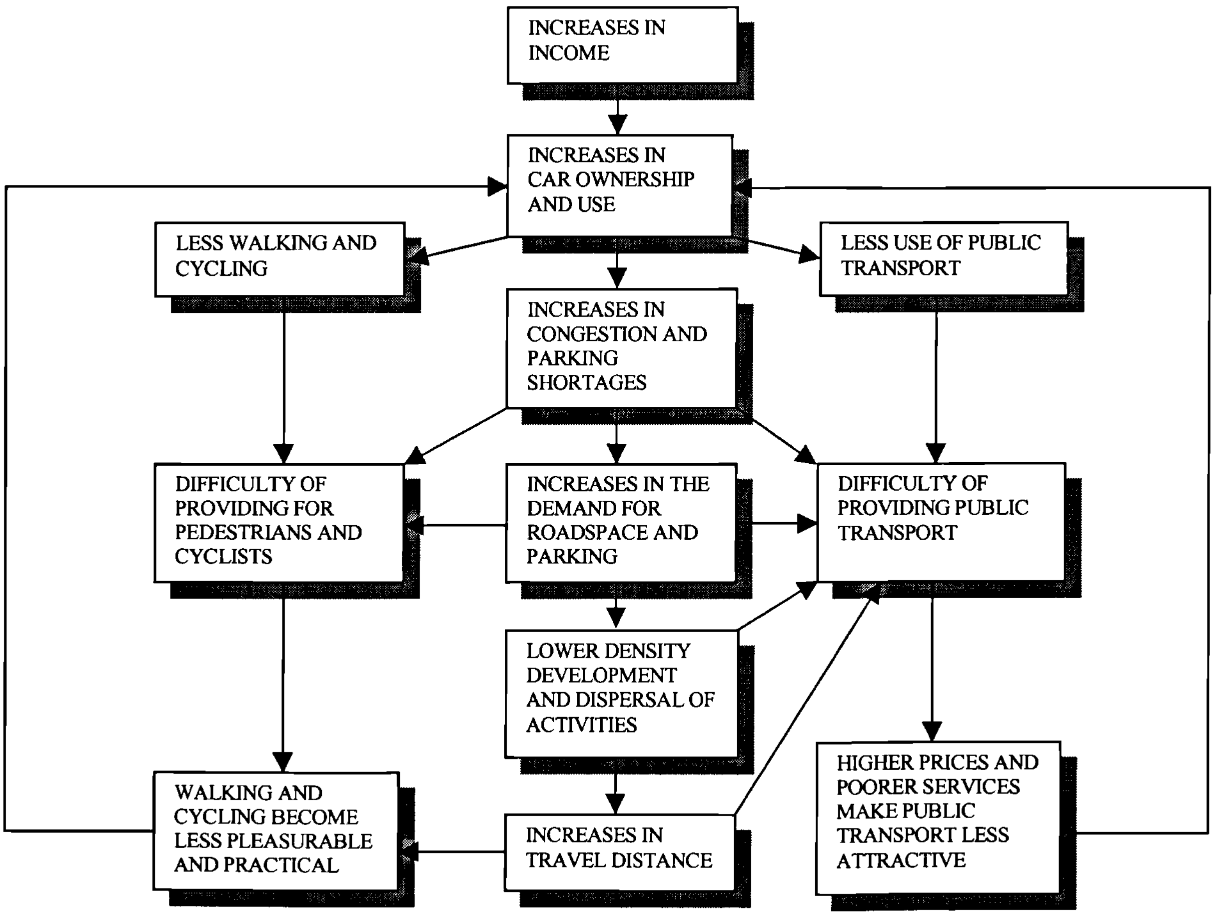
Business travel distance experienced a 28 per cent increase between 1984/85 and 1994/96 due mainly to the growth in the number of business trips. Business journeys are longer than many other types of journey – over 20 miles on average. The length of business journeys experienced a small increase (by 5 per cent) between 1984/85 and 1994/96.

Education escort journeys have experienced the largest rate of growth in travel distance between 1984/85 and 1994/96. Their frequency increased by 69 per cent over a decade, whilst average journey distance increased by 20 per cent. Although education escort journeys only account for around 3 per cent of all journeys, around twenty per cent of car journeys are for school escort purposes at peak times, contributing substantially to morning traffic congestion (Department of Transport, 1995a).

2.3 THE DRIVING FORCES BEHIND RECENT TRAVEL TRENDS

A number of driving forces behind these travel trends can be identified. These include increases in income, the growth in car ownership, increases in the relative cost of travel by public transport, decreases in public transport services and population and land use changes such as the dispersal of population and activities and the centralisation of services and facilities. Many of these driving forces are interlinked and can lead to a vicious circle of increasing travel demand (Figure 2.1).

FIGURE 2.1 THE INTERACTION OF DRIVING FORCES BEHIND TRAVEL TRENDS



Adapted from: Royal Town Planning Institute (1991) and Pharoah (1992).

The number of cars per capita in Great Britain increased by 20 per cent in the between 1985 and 1995 (Department of the Environment, Transport and the Regions, 1997b), fuelled by increases in disposable income and decreases in the relative cost of car travel (Department of the Environment, 1996a). Over the last decade, public transport fares rose and services declined, particularly after bus deregulation in 1986 (ibid.). Increasing concerns about personal safety and road safety acted to reduce walking and cycling, modes perceived to be more vulnerable. Population changes such as urban depopulation and rural population growth added to increased travel distances and reduced the proportion of journeys capable of being travelled by foot or by bicycle. Land use decisions such as the dispersal of employment to urban periphery business parks also increased travel distance and the reliance on the car. The impacts of recent trends in land use on travel patterns are discussed below, focusing on the effects of the dispersal of population and activities and the centralisation of services and facilities.

2.3.1 The Dispersal of Population and Activities

Evidence from previous censuses highlights a continuing decline in population in large urban areas and an increase in population in rural areas (Table 2.4). Between 1981 and 1991, the population of London and the metropolitan districts fell by approximately 903,000, whilst the population of the rest of England and Wales increased by approximately 846,000 (Breheny and Rockwood, 1993).

The population dispersal trends between 1981 and 1991 are a continuation of trends over a longer timescale of 30 years or more (see for example Fielding and Halford, 1990). Rural areas have experienced highest population increases in percentage and absolute terms. These changes in population have been accompanied by shifts in employment and retailing but evidence suggests that the dispersal is associated with longer travel distances, fewer journeys by foot or bicycle and the increased reliance on private transport (ECOTEC, 1993). Travel distance in rural areas is more than 50 per cent higher than in large metropolitan areas, whilst travel distance by foot in rural areas is more than half than that in metropolitan areas (ibid.).

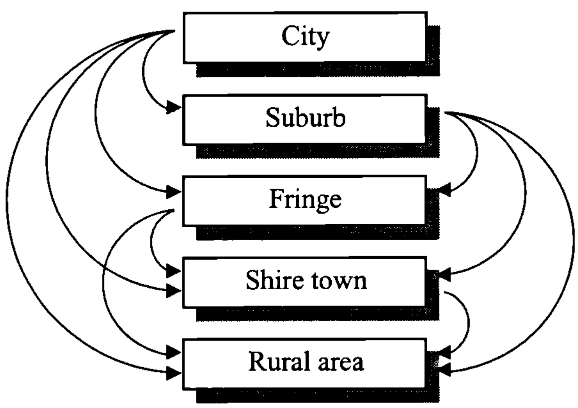
At the same time as the dispersal of population, employment, leisure and retail developments have moved to outer city locations and to small and medium-sized settlements. Flows in population have often led the flows in employment but much employment is still within large urban areas. Current flows in population are following a ‘counterurbanisation cascade’ in which the population is steadily moving from larger to smaller towns and cities and from inner urban areas to peripheral and more remote areas (Figure 2.2).

TABLE 2.4 POPULATION CHANGE IN ENGLAND AND WALES BETWEEN 1971 AND 1991

	1961-1971		*1971-1981*		*1981-1991*	
	population increase (x 1,000)	*population increase (%)*	*population increase (x 1,000)*	*population increase (%)*	*population increase (x 1,000)*	*population increase (%)*
London:						
• inner London boroughs	-461	-13.2	-535	-17.7	-147	-5.9
• outer London boroughs	-81	-1.8	-221	-5.0	-171	-4.2
Metropolitan Districts:						
• principal cities	-355	-8.4	-386	-10.0	-258	-7.4
• others	+412	+5.5	-160	-2.0	-327	-4.2
Non-metropolitan Districts:						
• large cities	-41	-1.4	-149	-5.1	-98	-3.6
• smaller cities	+38	+2.2	-55	-3.2	+5	+0.3
Industrial Districts:						
• Wales and N regions	+118	+1.3	+42	+1.3	-72	-2.1
• rest of England	+342	+5.0	+158	+5.0	+59	+1.8
New Towns	+337	+21.8	+283	+15.1	+133	+6.1
Resort and Retirement	+3,461	+2.2	+156	+4.9	+174	+5.2
Mixed and Accessible Rural:						
• outside SE England	+6,272	+1.9	+307	+8.8	+156	+4.1
• inside SE England	+9,602	+2.1	+354	+6.8	+162	+2.9
Remote Largely Rural	+399	+9.7	+468	+10.3	+328	+6.4
England and Wales	+2,629	+5.7	+262	+0.5	-57	+0.1

Source: Breheny and Rockwood (1993).

FIGURE 2.2 THE 'COUNTERURBANISATION CASCADE' OF POPULATION



Source: Champion et al (1998).

The development of out-of-town shopping centres and retail parks has added to the use of greenfield land and has also contributed to the decline of town and city centres. Large out of town retail centres (those a floorspace greater than 5,000 square metres) covered an estimated 1.4 million square metres in 1985 and almost 4.7 million square metres by the end of 1990, representing more than a three-fold increase in 5 years (Department of the Environment, 1996a). Slower growth in economic activity since 1990 has caused a slowdown in out of town development but the increase in out of town development has continued.

The dispersal of population and activities has clearly increased the development pressure on greenfield land although the use of greenfield land for housing was reduced in the last decade (Department of the Environment, Transport and the Regions, 1997a). Over half of the area of new housing was developed on greenfield land in 1985 whereas just under 40 per cent of the area of new housing was built on greenfield land in 1994. The consumption of greenfield land nevertheless continues albeit as a smaller proportion of all land used. The consumption of greenfield land could increase if the supply of brownfield land falls. According to recent government forecasts the increase in new households between 1991 and 2016 may be 4.4 million (HM Government, 1996). Assuming that 40 per cent of these new households are built on greenfield sites at a gross density of 40 houses per hectare (which is well above the average local authority density standard reported by Breheny and Archer, 1998), 44,000 hectares of greenfield land is required, or 1,760 hectares per year. A similar amount of land may be required to accommodate the development of industry, commerce and transport infrastructure.

2.3.2 The Centralisation of Services and Facilities

Many different types of services and facilities have been centralised, where fewer, larger services and facilities have replaced a large number of small-scale ones. Examples include shops, schools and hospitals. The total number of retail outlets has declined by more than 15 per cent over the last decade, whilst the number and proportion of supermarkets has increased (Central Statistical Office, 1997). Supermarkets have eroded the profitability of smaller shops and forced some out of business. Many supermarkets are at edge of town or out of town locations which are not conducive to short journeys and encourage shopping by car. Smaller schools have been closed and the concept of school catchments has lessened as a consequence of the increasing emphasis on parental choice (see for example Stead and Davis, 1998). These factors have acted to increase travel distances and increase reliance on motorised forms of transport. Similarly smaller hospitals have been closed because it is claimed that larger hospitals are needed to provide specialised treatment. Elkin et al (1991 p.69) argue however that specialised treatment is a small part of medical care and that a larger number of smaller medical facilities would be preferable from the perspective of both patient and service provider.

In addition to the centralisation of existing services and facilities, few new services and facilities have been provided in major new residential developments. A study of facility provision and travel patterns in five major new housing developments in the west of England, each containing more than 1,000 houses, reveals a paucity of provision (Farthing et al, 1997). None of the developments had their own bank, only one area had a secondary school and two developments did not have a post office or primary school. Evidence from the same study suggests that local provision of facilities may not have a significant impact on the increasing journeys by foot but at least is likely to be associated with shorter journeys.

Various economic, social and quality of life factors have influenced the land use changes described above but one of the most important factors has been the cost of transport. The real price of fuel and oil fell by almost 8 per cent between 1975 and 1995. The real cost of car travel, including the costs of insurance, servicing, repairs, road tax, fuel and oil, also fell (Department of the Environment, 1996a). During the same period the cost of bus and rail travel increased by over 50 per cent in real terms, higher than the increase in disposable income. Thus car travel became more affordable whilst public transport became more expensive.

The land use trends outlined above have clearly influenced the self-containment of settlements. Breheny (1992a) reports changes in the self-containment of new towns in Britain and comparable towns in southern England between 1951 and 1981, showing how self-containment in settlements reached a peak in the mid-1960s before the growth in mass car ownership and how self-containment has since declined. It is likely that land use trends such as the dispersal of population and activities and the centralisation of services in combination with increasing levels of car ownership and use have led to the declining self-containment of settlements.

2.4 POLICY RESPONSES

Transport policy has undergone major changes in Britain over the last decade. International agreements such as those made in Rio in 1992 on sustainable development, biodiversity and climate change are now embedded in current transport and land use policy. More recent agreements such as those from Kyoto on carbon dioxide emissions are soon likely to permeate policy. Influences on national policy have also come from Europe in the form of EU policy statements (the Common Transport Policy for example), action plans, green papers (such as the Green Paper on the Urban Environment and the Green Paper on Transport and the Environment) and directives (on vehicle emissions for example). The combination of these international influences with increasing local concerns about transport and environment issues have resulted in greater emphasis on more sustainable policies. Various recent policy responses aimed at reducing many of the environmental impacts caused by transport are outlined below. These include economic instruments, land use planning legislation and guidance, standards for air quality and vehicle emissions and targets for pollution and traffic levels. The government has also recently announced its intention to produce a White Paper on quality of life issues in urban areas which is likely to review and enhance a number of these policy responses. The Urban White Paper promises to consider a wide range of policies including transport, planning, housing and sustainable development (Department of the Environment, Transport and the Regions, 1998b).

One of the main policies used in the United Kingdom to reduce the environmental impacts of transport has been the steady increase in fuel duty. It is arguable however whether the increases in fuel price have begun to take effect. Some of the increases have been offset by reductions in the retail price of fuel before tax. Evidence from new car sales figures suggests that the proportion of small-engined cars (less than 1.4 litres) sold in the United Kingdom has not increased in the last few years (in fact, the proportion decreased from 46 per cent in 1994 to 40 per cent in 1996). On the other hand the average fuel consumption of new cars fell during this period, although the figures do not include four-wheel drive vehicles which are becoming an increasingly significant component of the vehicle fleet. Lower road taxes for cleaner cars and buses were announced in the 1998 Budget (HM Treasury, 1998).

A number of changes in the land use planning system have taken place over the last decade. Much of the planning policy guidance for local authorities, issued by national government, has been revised during this time. Some are now being reviewed for a second time (see section 4.3). This includes advice to local planning authorities on reducing the need to travel and encouraging less polluting transport choices (set out in Planning Policy Guidance note 13). The content of these documents is set out in more detail in chapter 4.

Recent government guidance to local authorities on developing local air quality strategies recognises the importance of traffic management measures and land use planning in improving air quality. Separate guidance on these two areas of policy (traffic management and land use planning) has also recently been issued. The guidance on air quality and traffic management (Department of the Environment, Transport and the Regions, 1997d) identifies a range of measures that might be used to reduce transport emissions including access restrictions, changing traffic flows, regulating traffic speed, promoting public transport and encouraging less polluting modes.

The guidance on air quality and land use planning guidance specifies that all local planning authorities are expected to have regard to national air quality objectives when preparing development plans and also have regard and refer to any Air Quality Management Area action plan (Department of the Environment, Transport and the Regions, 1997f). The guidance discusses the role of both local and regional planning in improving air quality and draws the attention of local planning authorities to the fact that air quality is capable of being a material planning consideration in some planning decisions. The guidance on air quality and land use planning guidance also highlights the role of other land use planning procedures and guidance that may assist air quality management (environmental assessment procedures or planning policy guidance notes for example).

In fulfilment of part of the 1995 Environment Act, the United Kingdom National Air Quality Strategy identifies government policy on the assessment and management of air quality. The strategy sets out a number of health-based air standards, air quality objectives to be achieved by 2005 and the process by which the objectives are to be achieved (Department of the Environment, 1997a). The Strategy includes standards and air quality objectives for a number of pollutants caused predominantly by transport. These include carbon dioxide, nitrogen oxides, particulates (PM_{10}) and aromatic hydrocarbons such as benzene and 1,3-butadiene.

New vehicles are required to comply with emission limits set at the European level (Table 2.5). These limits came into effect in 1993 and are part of a three-stage process whereby emissions of carbon monoxide, hydrocarbons, nitrogen oxides and particulates from new cars are controlled. Emissions from light and heavy goods vehicles area also being progressively tightened by similar European-wide limits.

TABLE 2.5 EUROPEAN VEHICLE EMISSION STANDARDS

	Emission Limits For Cars (grams per kilometre) Carbon monoxide (CO)	*Hydrocarbons (HC)*	*Nitrogen oxides (NO_X)*	*Particulate matter (PM)*
STAGE I (1 January 1993):				
petrol and diesel	3.16	1.13	1.13	0.18
STAGE II (1 January 1997):				
petrol	2.20	0.50	0.50	–
diesel	1.00	0.70	0.70	0.08
STAGE III (1 January 2000):				
petrol	2.30	0.20	0.15	–
diesel	0.64	–	0.50	0.05

Sources: Royal Commission on Environmental Pollution (1997) and Commission of European Communities (1998).

The United Kingdom is committed to stabilising its carbon dioxide emissions between 1990 and 2000 after agreements made at the 1992 United Nations Conference on Environment and Development in Rio. More recently the United Kingdom set itself the ambitious reduction target of a 20 per cent cut in carbon dioxide emissions between 1990 and 2010 (Department of the Environment, Transport and the Regions, 1998c). Recent carbon dioxide projections suggest that emissions may begin to increase soon after 2005 and indicate that the target may be difficult to achieve unless emissions from transport (and other sectors) are substantially reduced (Department of Trade and Industry, 1995).

The 1997 Road Traffic Reduction Act requires local authorities responsible for transport planning to produce a report containing an assessment of existing traffic levels on its roads, a forecast of expected growth in these levels and targets for reducing the level of road traffic or its rate of growth[1]. Traffic targets will become an integral part of the preparation of Transport

1. The 1997 Road Traffic Reduction Act only relates to local traffic and not to traffic on motorways and trunk roads.

Policies and Programme submissions and bids by local authorities to the Department of the Environment, Transport and the Regions (Department of the Environment, Transport and the Regions, 1997g).

2.5 SUMMARY

Transport is one of the largest sources of environmental pollution. The large number of significant environmental impacts associated with transport range from local through to global. The impacts span a large range of issues including air quality, energy use, waste production and health. Some of these impacts are increasing, such as carbon dioxide emissions. Other impacts are beginning to decrease but these may start to increase again in the longer term unless action is taken to reduce transport growth. Examples include emissions of nitrogen oxides and particulates. In addition to these environmental impacts, there are also a number of social and economic impacts associated with transport.

The travel trends contributing to the environmental impacts of transport include the increasing distance being travelled per person. Journey frequency has remained relatively constant over the last decade whereas the average journey length has increased by almost one-fifth. The reliance on more environmentally polluting modes such as cars and taxis has increased, whilst the use of less environmentally damaging modes such as walking and cycling has decreased. The car accounts for more than 80 per cent of all distance travelled and almost 60 per cent of all journeys in Britain. The average total distance travelled per person by car is over 5,000 miles per year. Journeys by foot account for more than a quarter of all journeys but only 3 per cent of all travel distance since journeys by foot are usually short (just over half a mile on average). The frequency of journeys by foot decreased by 13 per cent between 1985/86 and 1994/96, whilst the average journey length remained constant. Even short journeys under 2 miles are now often undertaken by car rather than by foot or bicycle.

The main journey purposes that account for much of the annual distance travelled per person (in order of importance) are social purposes (visiting friends, entertainment), commuting, recreation (sport, holidays, day trips), shopping and business purposes. These five journey purposes account for over 80 per cent of the distance travelled per person. All of these purposes have experienced increases in distance over the last decade. The journey purposes that experienced the most rapid rate of growth in total distance over the last decade were education escort, shopping and holiday journeys.

A number of driving forces behind these travel trends can be identified. These include increases in car ownership, the relative cost of travel by car and public transport, increasing concerns about personal safety and road safety, population changes and land use decisions. Many of these driving forces are interlinked. The number of cars per capita in Great Britain increased by 20 per cent in the between 1985 and 1995 (Department of the Environment, Transport and the Regions, 1997b), fuelled by the relative cost of car travel which fell in real terms and as a proportion of disposable income over this period (Department of the Environment, 1996a). Over the last decade there was a decline in public transport availability which accelerated after bus deregulation in 1986 and an increase in the relative cost of public transport (Department of the Environment, 1996a). Increasing concerns about personal safety and road safety acted to reduce the use of modes that are perceived to be more vulnerable such as walking and cycling, whilst population changes such as urban depopulation and rural population growth have added to increased travel distances and reduced the proportion of journeys capable of being travelled by foot or by bicycle. Land use decisions such as the dispersal of employment to urban periphery business parks have also acted to increase travel distance and reliance on the car.

The population dispersal trends between 1981 and 1991 are a continuation of trends over a longer timescale. Rural areas have experienced highest population increases in percentage and absolute terms. These changes in population have been accompanied by shifts in employment and retailing but evidence suggests that the dispersal is associated with longer travel distances. Employment, leisure and retail developments have moved to outer city locations and to small and medium-sized settlements. The development of out-of-town shopping centres and retail parks has added to the use of greenfield land and has also contributed to the decline of town and city centres. Many different types of services and facilities have been centralised, where fewer, larger services and facilities have replaced a large number of small-scale ones. Examples include shops, schools and hospitals. The total number of retail outlets has declined by more than 15 per cent over the last decade, whilst the number and proportion of supermarkets has increased. Supermarkets have eroded the profitability of smaller shops and forced some out of business. Many supermarkets are at edge of town or out of town locations which are not conducive to short journeys and encourage shopping by car. Smaller schools have been closed and the concept of school catchments has lessened as a consequence of the increasing emphasis on parental choice.

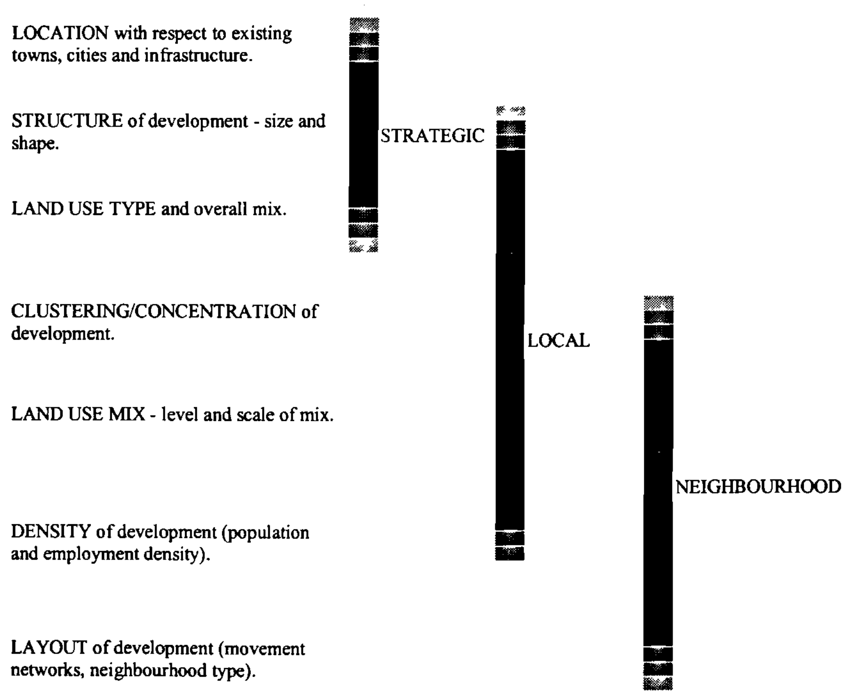
Various economic, social and quality of life factors have influenced the land use changes described above but one of the most important factors has been the cost of transport. The real price of fuel and oil fell over the last two decades. During the same period, the cost of bus travel increased at a rate higher than the increase in disposable income. Thus car travel became more affordable whilst public transport became more expensive.

There have been a number of policy responses aimed at reducing the environmental impacts of transport over the last decade. Responses have included economic instruments, land use planning legislation and guidance, standards for air quality and vehicle emissions, targets for pollution and traffic levels and awareness and education campaigns. Land use planning is one of a number of approaches being used to tackle the environmental impacts associated with transport.

CHAPTER 3: REVIEW AND CRITIQUE OF OTHER STUDIES

Land use planning is one of a range of means to promote more sustainable development. A number of land use characteristics from regional to local in scale can affect travel patterns and influence the environmental impacts of transport. Planning policies at the strategic, local and neighbourhood scale influence these land use characteristics. At the strategic level, planning policies can influence the location of new development in relation to existing towns, cities and other infrastructure. Strategic policies can also influence the size and shape of new development and the type of land use: whether for example it is used for housing, commercial and industrial purposes or a mixture of these purposes. At the local level, planning policies can influence the level and scale of land use mixing and the extent to which development is clustered or concentrated into nodes. Planning policies can be used at the local and neighbourhood level to influence the density and layout of development (Figure 3.1).

FIGURE 3.1 LAND USE CHARACTERISTICS THAT MAY AFFECT TRAVEL PATTERNS



Adapted from: Owens (1986).

This chapter focuses on seven aspects of urban form, corresponding with the seven secondary research hypotheses of the study (section 1.2):

(i)	the distance from the urban centre	*Regional/strategic planning*
(ii)	the settlement size	
(iii)	the mixing of land uses	
(iv)	the provision of local facilities	
(v)	the density of development	
(vi)	the proximity to transport networks	
(vii)	the availability of residential parking	*Local/neighbourhood planning*

3.1 REVIEW APPROACH

This chapter reviews evidence for the influence of land use on travel patterns from empirical studies only[1]. The review is international although most of the studies reported in this chapter originate from either Western Europe or the United States. There are a number of reasons for the focus on empirical studies. First, empirical studies are fundamental and often provide data for use in the construction or testing of models. Second, empirical studies illustrate real examples and rely on fewer assumptions than modelling studies. Third, they are often more understandable and transparent in approach than modelling studies and allow a wide variety of land use characteristics to be examined, whereas modelling studies are often seen as 'black box' exercises which lack transparency about the complexity, subjectivity and assumptions of the model. They rely on mathematical formulations that are often incomprehensible to most people, including many land use policy-makers. It would be unfair however to point to the weaknesses of modelling studies without also recognising that there are weaknesses of empirical studies. Empirical studies do not easily lend themselves to establishing the causality of relationships or conclusive results. The empirical investigation of relationships between selected land use characteristics and travel patterns relies on examples of land use characteristics being found in the 'field'. There are often confounding factors (such as socio-economic characteristics) which make comparisons between different areas difficult in empirical studies. Certain land use characteristics are difficult to classify in the 'real world' since they often lie between different classification systems (centralised or dispersed

1. For literature on land use and transport modelling studies and their application to land use planning, see for example Webster et al (1988), Wegener (1994) or Wilson (1998).

employment, mixed or segregated land uses for example). The strengths and weaknesses of the empirical approach adopted in this particular study are discussed in more detail in section 6.3.

3.2 Review

There is a large amount of literature on the relationships between land use and travel characteristics. This review synthesises this material using a matrix approach in which land use characteristics form one axis and travel characteristics[1] form the other axis. Using this approach it is possible to identify where research has been concentrated and where there are gaps in the research. It is also possible to examine where findings are similar and where they differ. Possible explanations are suggested for differences of opinion between research findings. Table 3.1 presents a summary matrix showing how empirical studies have been classified according to different measures of land use characteristics and travel patterns.

1. There are a variety of ways in which travel demand and modal choice can be measured. The literature review is divided according to five measures of travel patterns:
(i) modal split
(ii) travel distance
(iii) transport energy consumption
(iv) travel time
(v) journey frequency

TABLE 3.1 STUDIES CLASSIFIED ACCORDING TO LAND USE CHARACTERISTICS AND TRAVEL PATTERNS

	Land use characteristics → Travel patterns ↓	*Distance from the Urban Centre*	*Settlement Size*	*Mixing of Land Uses*	*Provision of Local Facilities*	*Density of Development*	*Proximity to Main Transport Networks*	*Availability of Residential Parking*
DISTANCE	Average journey distance	Gordon et al, 1989a Johnston-Anumonwo, 1992 Spence & Frost, 1995			Cervero & Landis, 1992 Hanson, 1982 Winter & Farthing, 1997	ECOTEC, 1993		
	Average journey distance by car		Hillman & Whalley, 1983		Cervero & Landis, 1992 Farthing et al, 1997	ECOTEC, 1993 Hillman & Whalley, 1983 Levinson & Kumar, 1997	Levinson & Kumar, 1997	
	Travel distance (all modes)	Næss et al. 1995 Curtis. 1995	ECOTEC, 1993 Hillman & Whalley, 1983			ECOTEC, 1993 Hillman & Whalley. 1983	Headicar & Curtis, 1994	
FREQ.	Journey frequency	Curtis, 1995		Ewing et al, 1996	Hanson, 1982; ECOTEC, 1993	ECOTEC, 1993 Ewing et al, 1996		
MODE	Proportion of car journeys	Curtis. 1995 Næss & Sandberg. 1996	Gordon et al. 1989a		Cervero & Landis, 1992	ECOTEC, 1993 Gordon et al, 1989a Levinson & Kumar, 1997	Headicar & Curtis, 1994 Kitamura et al. 1997	Kitamura et al, 1997
	Proportion of public transport journeys				Cervero & Landis, 1992	ECOTEC, 1993 Frank & Pivo, 1994 Levinson & Kumar, 1997	Cervero, 1994	
	Proportion of walk/bike journeys			Cervero, 1989 & 1996.	Winter & Farthing, 1997	ECOTEC, 1993 Kitamura et al, 1997 Frank & Pivo, 1994		Balcombe & York, 1993
TIME	Travel time		Gordon et al, 1989a	Giuliano & Small, 1993	Cervero & Landis, 1992	Gordon et al, 1989a Gordon et al, 1991 Levinson & Kumar, 1997	Levinson & Kumar, 1997	
ENERGY	Transport energy consumption		Næss et al, 1995 Mogridge, 1985 Newman & Kenworthy, 1988			Næss, 1993 Newman & Kenworthy, 1989		

3.2.1 Distance from the Urban Centre

Spence and Frost (1995) describe the changes in commuting distance between 1971 and 1981 in the three largest cities in Great Britain, London, Manchester and Birmingham and show how commuting distance changes with increasing distance between home and the urban centre. In London commuting distance increases almost linearly with distance between home and urban centre. At a distance of 20 kilometres from the centre of London commuting distance continues to increase with increasing distance from the centre of the city. In Manchester and Birmingham however the relationship is different. Commuting distance in Birmingham first increases with increasing distance between home and the urban centre but at a distance of around 7 kilometres from the urban centre commuting distance reaches a plateau. At a distance of around 9 kilometres from the centre commuting distance begins to decrease as distance from the urban centre increases. Commuting distance in Manchester first increases with increasing distance from the urban centre. At a distance of around 5 kilometres from the centre commuting distance reaches a plateau and does not change with further increases from the city centre unlike the trend in commuting distance in Birmingham which begins to decrease at a distance of 9 kilometres from the city centre. The trends in commuting distance by distance from home to the urban centre in the three cities between 1971 and 1981 are similar. Gordon et al (1989a) describe the changes in average travel distance in the United States between 1977 and 1983 of people residing inside and outside cities. In various sizes of city journey distances for both work and non-work journeys in 1977 and 1983 were almost always lower for residents inside cities than for residents outside cities.

Næss et al (1995) identify a statistical relationship between the distance from the urban centre and travel distance per person in Oslo in which total distance increases with increases between home and the urban centre. It is claimed that the distance between home and the urban centre is an important determinant of travel distance in addition to factors such as car ownership and the proximity to local facilities from the home. In a study of travel patterns in various locations in and around Oxford, Curtis (1995) shows that the distance between home and urban centre may be linked to average work journey distance. A link between average non-work journey distance and the distance from home to urban centre is much less apparent. Average work journey distance is lowest in the two locations closest to the centre of Oxford (Botley and Kiddlington) and highest in the two locations furthest from the centre of Oxford (Bicester and Witney). As for non-work journeys, average travel distance is highest in

Witney, Bicester and Botley, the first two locations being most distant from the city centre and the latter being closest to the centre of Oxford. The lowest average non-work travel distance was recorded in Kiddlington, a location close to the centre of Oxford. According to the data collected by Curtis (1995) the frequency of work and non-work journeys does not vary significantly according to the distance between home and the urban centre. The proportion of journeys by car may be related to some extent to the distance between home and city centre. The proportion of car journeys is lowest in the two locations closest to the centre of Oxford and highest in the two locations furthest from the city centre.

Næss et al (1995) examine the effect of distance from the home to the urban centre on transport energy consumption. Transport energy consumption increases as the distance between home and the urban centre increases. A causal model containing a variety of land use and socio-economic variables is constructed. It is claimed car ownership has the greatest influence on transport energy consumption, followed by the distance between home and the urban centre, the proximity to local facilities from the home, income per capita and various other socio-economic factors. Mogridge (1985) demonstrates a near linear relationship between distance from home to the centre and transport energy consumption. The relationship is shown to be very similar in both London and Paris. On average, residents living at a distance of 15 kilometres from the urban centre consume more than twice the transport energy consumed by residents living 5 kilometres from the urban centre. Similarly, Newman and Kenworthy (1988) identify the relationship between transport energy consumption and the distance from the central business district in Perth. Like Mogridge (1985), Newman and Kenworthy demonstrate a linear relationship although the latter is not as steep. It is reported that residents living at a distance of 15 kilometres from the central business district consume approximately 20 per cent more transport energy than residents living 5 kilometres from the central business district.

In summary, studies indicate that the increasing distance from home to the urban centre is associated with increasing travel distance, an increasing proportion of car journeys and increasing transport energy consumption. Trip frequency however does not seem to vary significantly according to the distance between home and the urban centre.

3.2.2 Settlement Size

The size of settlements affects the range of local jobs and services that can be supported and influences the range of public transport services which can be provided. Thus small settlements that are unable to support a large range of services and facilities may force local residents to travel longer distances in order to access the services and facilities that they require. Very large, centralised settlements may on the other hand lead to longer travel distances as the separation between homes and the urban centre becomes large. Large settlements with a very large range of jobs and services may also attract people living long distances away to travel to them. These factors may all influence travel patterns. According to Owens (1986 p.29) and ECOTEC (1993 p.39) it is unlikely that there is a simple relationship between settlement size and travel patterns. Banister (1996) argues that a diversity of services and facilities requires a population size of at least 10,000. Barton et al (1995) share similar views on settlement size thresholds.

According to analysis of data from 1985/86 National Travel Survey of Great Britain, ECOTEC (1993) report that travel distance is highest in the smallest category of settlements (containing fewer than 3,000 residents) and travel distance is lowest in large metropolitan areas (excluding London). Residents of London travel larger distances on average than the residents of the six next largest metropolitan areas (West Midlands, Greater Manchester, West Yorkshire, Glasgow, Liverpool and Tyneside). Hillman and Whalley (1983) report similar findings in their analysis of data from 1978/79 National Travel Survey of Great Britain. They also report that the total distance travelled per person by car is lowest in conurbations (metropolitan areas) and highest in rural areas. The average journey distance by car is also lowest in conurbations and highest in rural areas.

Figures from research by Gordon et al (1989a) show no easily identifiable relationship between urban population size and modal choice. In a study of commuting patterns in the ten largest urbanised areas in the United States, the proportion of car journeys was found to be least in New York (which has the largest population of the areas studied) and highest in Detroit (which has the sixth largest population of the areas studied).

Breheny (1995) uses estimates of typical specific energy consumption by mode and data from the 1985/86 National Travel Survey of Great Britain to calculate transport energy consumption by population size. He reports that transport energy consumption is lowest in metropolitan areas (excluding London) and highest in the smallest category of settlements (containing fewer than 3,000 residents). Transport energy consumption is one third lower than average in the metropolitan areas (excluding London) and more than one third higher than average in the smallest settlements. Breheny's work shows that the trends in transport energy consumption and travel distance trends by settlement size are very similar despite significant variations in modal split across different sizes of settlement. Although there are significant differences in energy consumption across different sizes of settlement, Breheny estimates that counter-urbanisation trends between 1961 and 1991 have only been responsible for a small increase (approximately 2 per cent) in passenger transport energy consumption.

In summary, there has been a relatively large amount of research concerning the relationship between settlement size and travel patterns. The effect of distance from home to the urban centre has perhaps been examined in more detail. Owens (1986 p.29) and ECOTEC (1993 p.39) claim that the relationship between settlement size and travel patterns is unlikely to be simple due to the interplay of competing factors. Evidence from Great Britain shows that large metropolitan settlements are associated with low travel distance and transport energy consumption. Evidence from the ten largest urban areas in the United States however shows no easily identifiable relationship between urban population size and modal choice.

3.2.3 The Mixing of Land Uses

The mixing of land uses affects the physical separation of activities and is therefore a determinant of travel demand. Some evidence suggests that the mixing of land uses is not as important as density in influencing travel demand (Owens, 1986; ECOTEC, 1993). Nevertheless the level of mixed use may contribute to travel demand particularly through the decentralisation of less specialised employment (ECOTEC, 1993). The mixing of land uses is commonly measured using job ratio, the ratio of jobs in the area to workers resident in that area.

Ewing et al (1996) have investigated the effect of the various land use mix characteristics on trip generation including the balance of homes and jobs. They report that there is no statistically significant relationship between the balance of homes and jobs and journey frequency. In a study of commuting patterns in San Francisco, Cervero (1989) reports a negative relationship between job ratio and the proportion of journeys undertaken by foot and cycle: where there are many more jobs than houses the proportion of journeys by foot or cycle falls. Cervero concedes that the statistical relationship is not very strong but suggests that the encouragement of balancing houses and jobs may encourage walking and cycling. Giuliano and Small (1993) question the importance of job ratio on travel patterns and present the results of a commuting study in the Los Angeles region to show that job ratio has a statistically significant but relatively small influence on commuting time. They conclude that attempts to alter the metropolitan structure of land use are likely to have small impacts on commuting patterns even if jobs and housing became more balanced. In a study of transport energy consumption in various locations in Great Britain, Banister et al (1997) identify a relationship between job ratio and energy use per trip in one of their case studies (Oxford).

There are relatively few studies concerning the effect of job ratio on travel patterns. Evidence from existing research may appear contradictory but this is not necessarily the case. The three studies summarised above use different measures of travel patterns in their analysis. Thus it is quite consistent that the relationship between job ratio and modal share (examined by Cervero, 1989) is not the same as the relationship between job ratio and travel time (examined by Giuliano and Small, 1993) or the relationship between job ratio and transport energy use per trip (examined by Banister et al, 1997).

3.2.4 The Provision of Local Facilities

The provision of local facilities and services may clearly reduce travel distance and increase the proportion of short journeys capable of being travelled by non-motorised modes. Little evidence has been collected on this subject however and some of the precise impacts of local facilities and services on travel patterns are unknown.

Winter and Farthing (1997) report that the provision of local facilities in new residential developments reduces average trip distances but does not significantly affect the proportion of journeys by foot. Evidence from the same study reported elsewhere indicates that the provision of local facilities reduces the average journey distance by car (Farthing et al, 1997). ECOTEC (1993, p.47) report from neighbourhood case studies that a clear relationship emerges between the distance from a local centre, the frequency of its use and average journey distance. Hanson (1982) reports similar findings, showing that the proximity to local facilities is positively associated with average distance after taking into account the effects of various socio-economic differences of the areas studied. Hanson also shows that the provision of local facilities is associated with increased journey frequency although the effect of increasing journey frequency is not as strong as the effect of reducing trip length.

There is broad consensus from these studies about the effects of local facilities and services on travel patterns. The provision of local facilities may contribute to less overall travel but may not contribute to any more travel by less energy intensive modes, namely walking and cycling.

3.2.5 The Density of Development

The density of development is commonly measured in terms of population density and to a lesser extent employment density. Much of the research into land use and travel patterns has focused on the relationship between population density and travel patterns. ECOTEC (1993 p.33) put forward four reasons why population density may be linked to travel patterns. Firstly, higher population densities widen the range of opportunities for the development of local personal contacts and activities that can be maintained without resort to motorised travel. Secondly, higher population densities widen the range of services that can be supported in the local area, reducing the need to travel long distances. Thirdly, higher density patterns of development tend to reduce average distances between homes, services, employment and other opportunities which reduces travel distance. Fourthly, high densities may be more amenable to public transport operation and use and less amenable to car ownership and use which have implications for modal choice.

Figures derived from ECOTEC (1993, pp.33-34) indicate that average journey distance by car, bus and rail decreases with increasing population density, whilst the average journey distance by foot is more or less constant regardless of population density. Hillman and Whalley (1983) report similar findings from their analysis of data from the 1978/79 National Travel Survey of Great Britain. They show that the total distance by all modes decreases with increasing population density and show that residents of very low-density areas (less than 5 persons per hectare) travel by car more than twice the distance of residents of high-density areas (more than 60 persons per hectare).

According to ECOTEC (1993), total journey frequency does not show a clear gradation with population density and there is little variation in trip frequency according to population density. The average journey frequency is reported to be close to 14 journeys per person per week. The highest trip frequency is 14.8 journeys per person per week (6 per cent higher than average) in areas where population density is between 1 and 5 persons per hectare. The lowest trip frequency is 13.0 journeys per person per week (7 per cent lower than average) in areas where population density is more than 50 persons per hectare. Ewing et al (1996) report that there is a weak significant statistical link between trip frequency and population density.

Figures from ECOTEC (1993) show how modal choice is associated with population density. The proportion of trips by car decreases with increasing population density whilst the proportion of trips by public transport and foot both increase. Car trips account for 71 per cent of journeys in low-density areas (more than 50 persons per hectare) but only 51 per cent of trips in high-density areas (less than 1 persons per hectare). There is a fourfold difference in public transport trips and almost a twofold difference in walk trips between very low density areas and very high density areas. Frank and Pivo (1994) show how the proportion of shopping trips by public transport and the proportion of commuting trips by foot are both positively linked with population density. Kitamura et al (1997) show how population density is linked to the proportion of public transport trips after accounting for socio-economic differences. Gordon et al (1989a) however produce evidence which shows that there is no clear relationship between the proportion of car trips and population density. There are a number of reasons for the apparently contradictory findings of these studies. First, the definitions of density are different in the work of Gordon et al than in most of the other studies. Second, Gordon et al (1989a) only focus on journeys to work whereas ECOTEC (1993) and Kitamura et al (1997) examine all journey purposes.

Newman and Kenworthy (1989) illustrate the correlation between urban population density and transport energy consumption in a study of 32 cities from around the world. Using Swedish data, Næss (1993) also identifies a link between population density and transport energy consumption.

There is much less evidence concerning the relationship between travel patterns and employment density, a second measure of the intensity of land use and activities. It is possible that similar relationships between population density and travel patterns exist between employment density and travel patterns. Frank and Pivo (1994) for example show that employment density, like population density, is connected to the proportion of public transport trips for both shopping and work journeys after controlling for socio-economic variations.

In summary, there is a growing body of research that suggests a link between population density and many measures of travel patterns. There is little evidence however of much variation in journey frequency by population density. In contrast to the amount of research into the relationship between population density and travel patterns, there has been little recent research concerning the relationships between employment density and travel patterns.

3.2.6 Proximity to Main Transport Networks

The proximity to transport networks also influences travel patterns and consequently transport energy consumption. Better access to major transport networks, particularly road and rail networks, increases travel speeds and extends the distance which can be covered in a fixed time. Major transport networks can be a powerful influence on the dispersal of development – both residential and employment development. The proximity to major transport networks may lead to travel patterns characterised by long travel distances and high transport energy consumption.

Headicar and Curtis (1994) report that the proximity to major transport networks has a substantial effect on work travel distance. They conclude that the proximity to either a motorway or a main road is associated with longer travel distances and a higher proportion of car journeys. They also report that the proximity to a railway station is associated with long distance commuting but fewer car journeys. Kitamura et al (1997) report that the distance from home to the nearest bus stop and railway station affects the modal share. The proportion of car journeys increases and the proportion of non-motorised journeys decreases with increasing distance from the nearest bus stop; the proportion of rail journeys increases with increasing distance from the nearest railway station. Cervero (1994) shows how the proportion of rail journeys decreases with increasing distance from the railway station. Residents living within 500 feet (approximately 150 metres) of a railway station in California typically use rail for approximately 30 per cent of all journeys. The further the distance from the railway station, the lower the proportion of rail journeys is made. Residents living at a distance of around 3,000 feet (approximately 900 metres) from the nearest railway station are likely to make only about half the number of rail journeys than residents living within 500 feet of a railway station. Cervero reports that this pattern of rail use is similar in Washington, Toronto, Edmonton and California.

3.2.7 The Availability of Residential Parking

Evidence from Kitamura et al (1997) shows that the availability of residential car parking is linked to both trip frequency and modal choice. As the availability of residential car parking increase the average number of trips per person decrease: an observation that is perhaps counter-intuitive. Kitamura et al suggest that residents with more parking spaces make fewer, longer journeys, whilst residents with fewer parking spaces make more journeys but these tend to be short. It is also reported that as the availability of residential car parking increase the proportion of car journeys increases. This would imply that residents with more parking spaces not only make fewer, longer journeys but also that these journeys are more car-based. Conversely, the research implies that residents with fewer parking spaces make more journeys but which are short and less car-based.

Balcombe and York (1993) identify a correlation between the availability of residential parking (expressed as the ratio of vehicles to spaces) and the proportion of car owners making short journeys by foot (in order to retain their parking space). The research indicates a greater tendency to walk in areas where residential parking is limited. Similarly, Valleley et al (1997) suggest a relationship between the modal split of commuting and parking provision at work.

3.3 CRITIQUE OF THE EVIDENCE

The critique of the studies summarised above is divided into two main sections. The first section concerns issues of data accuracy, reliability and quality. The second section addresses the applicability of various research methods.

3.3.1 Data Accuracy, Reliability and Quality

The question of whether the data is accurate and reliable is fundamental to all research. This section discusses a number of issues concerning data accuracy, reliability and quality that are relevant to some or all of the empirical studies reviewed above. A number of these issues originate from an article by Troy (1992) in a critique of two studies authored by Newman and Kenworthy (Newman et al, 1985; Newman and Kenworthy, 1989) since several of the issues he identifies are also applicable to other studies of land use and travel patterns.

The first issue concerns data accuracy. A number of studies concerning the effect of land use and travel patterns have involved the calculation of travel distance from trip zone data. Troy (1992) questions the accuracy of travel distance calculated by Newman et al (1985) from trip zone data where trip lengths are calculated from average distances between zone centroids. Some of the studies reported in section 3.2 also rely on trip zone data to calculate travel distance (Frost and Spence, 1995; Banister et al, 1997 for example). The distance of each journey is calculated according to the distances between the origin and destination zone centroids. Depending on the size of zones, the actual travel distance may be significantly different to the figure calculated using average centroid distances. The calculations also do not account for the configuration of the transport network in order to establish actual route distances rather than straight-line distances between origin and destination zones. Since most studies are comparative however precise distances are perhaps not as important as relative distances. Thus precise calculations of travel are less important than *comparable* travel distances that have a similar degree of accuracy for each area.

Second, Troy (1992) questions the applicability of average fuel consumption figures to calculate transport energy consumption without accounting for factors that affect transport energy consumption such driving conditions or the time of day. Similar assumptions are made in a number of other studies reported above (Banister et al, 1997, Breheny, 1995, Næss et al, 1995 for example). The average energy consumption of vehicles is influenced by a number of vehicle, journey and passenger characteristics such as vehicle age, fuel type, engine size, engine temperature, vehicle speed and passenger loading (or occupancy). To account for each of these factors for every journey would add much complexity to the calculation of energy consumption. It would be necessary to establish information about the vehicle age, fuel type, engine size, engine temperature, vehicle speed and passenger occupancy for every journey.

Because of concerns about the extent to which energy consumption figures are affected by vehicle, journey and passenger characteristics, these are examined in more detail later in the study (see section 4.3).

Third, the issue of the reliability of data from self-completed questionnaires is questioned. Troy (1992) states that there is evidence from several (unspecified) reports to suggest that this kind of travel diary systematically overstates household travel and understates short trips. It is not clear how travel diaries tend to overstate household travel but it is clear that short journeys may be under-recorded. Studies based on data from self-completed travel diaries and reported above include Cervero (1994), Cervero and Landis (1992); Curtis (1995), Kitamura et al (1997), Næss and Sandberg (1996), Næss et al (1995), Prevedouros and Schofer (1992), Winter and Farthing (1997). Clearly the issue of under-recorded short journeys is important when considering travel patterns such as trip frequency or the modal share of non-motorised journeys since short journeys may be a significant component. The under-recording of short journeys is perhaps of less importance when considering travel distance or transport energy consumption since short trips do not often substantially contribute to these two measures of travel.

The representativeness of travel data is related to the sample size, the type of journeys recorded and the time period over which the data is collected. Troy (1992) expresses concern about the representativeness of travel data collected over a short time, questioning whether the typical weekday travel data collected by Newman et al (1985) provide sufficient travel information to calculate annual transport energy consumption. Similar concerns might be expressed about a number of other studies summarised above. Concerns might also be expressed about the extent to which studies of single journey purposes (work travel for example) can be used to represent all purposes of travel. Commuting in Great Britain for example now accounts for fewer than a quarter of all trips and a similar proportion of travel distance (Department of Environment, Transport and the Regions, 1997e). The search for more sustainable land use patterns which is the focus of many recent studies of land use and travel patterns clearly depends on identifying areas which promote fewer journeys, shorter journeys and non-motorised journeys. These characteristics clearly do not just apply to one type of journey but all types. Thus the extent to which studies of commuting or other single types of journey purpose can identify sustainable land use patterns is only partial.

3.3.2 Methods of Analysis

There are limitations to all methods of analysis and the limitations of empirical studies have been outlined earlier in section 3.1. Two issues related to the limitations of empirical studies are discussed in this section. The first issue concerns the difficulty in establishing the causality of relationships. The second issue concerns socio-economic factors and the difficulty they pose in making comparisons between different areas.

Cross-sectional analyses of land use and travel patterns like the ones contained in the studies summarised in section 3.2 do not easily lend themselves to establishing causal links. Several studies demonstrate strong correlations between various measures of land use characteristics and travel patterns. Such analysis however cannot prove a causal relationship even where high correlation is demonstrated. Correlation may identify a link between variables but this link may or may not be direct. Even if the link is direct it is not possible to establish the direction of causality. Therefore a strong correlation between transport energy consumption and population density for example does not imply a direct link between the two variables. The two variables could be linked by one or more intermediate variables such as car ownership or income. Similarly, the results of regression analyses may identify statistical dependence between variables but do not identify a physical relationship between variables. As with correlation analysis, regression analysis may identify a link between variables but this link may or may not be direct.

In identifying a link between land use characteristics and travel patterns it is necessary to hold all other variables constant. This is not easy in empirical research since different land use characteristics are often associated with different socio-economic characteristics which also have an effect on travel patterns. The variation in socio-economic characteristics increases the difficulty in establishing the effect of land use characteristics on travel patterns and adds complication to the comparison of travel patterns in different areas.

A large number of socio-economic characteristics may influence travel patterns. There is a substantial amount of literature on this subject. This chapter does not present a comprehensive review of the effects of all socio-economic characteristics on travel patterns[1]. Instead it

1. For a more comprehensive review of the effect of socio-economic characteristics on travel patterns, seeDamm (1982) or Hanson (1982).

identifies some of the main types of socio-economic characteristics and illustrates how each of these main types of characteristics may affect travel patterns. The effects are summarised in Table 3.2.

TABLE 3.2 EXAMPLES OF THE EFFECTS OF SOCIO-ECONOMIC CHARACTERISTICS ON TRAVEL

Hanson (1982) reports that trip frequency is linked to *household income*: people in higher income households make more journeys than in lower income households. Cervero (1996) shows how commuting distance increases with increasing income. Næss and Sandberg (1996) identify a positive link between household income and the total distance travelled per person. Transport energy consumption is reported to increase as household income increases (Næss, 1993; Næss et al, 1995). Flannelly and McLeod (1989) show how income is linked to the choice of mode for commuting. Income is also linked to land use patterns which may explain some of the variation in travel patterns in different locations. Mogridge (1985) for example shows how average incomes in Paris and London increase with increasing distance from the city centre, with the exception of residents in very central locations (within approximately 4 kilometres of the city centre).

Hanson (1982) reports that trip frequency increases with *car ownership* whereas Prevedouros and Schofer (1992) contend that car availability does not explain the variation in trip frequency. Travel distance is reported to increase with car ownership (Næss and Sandberg, 1996), as is transport energy consumption (op. cit.) and the proportion of car journeys (Næss, 1993). Flannelly and McLeod (1989) show that the number of cars per household is linked to the choice of mode for commuting. Ewing (1995) reports that travel time increases as car ownership levels increase. Like income, car ownership is also linked to land use patterns and may explain some of the variation in travel patterns in different locations. Gordon et al (1989a), Levinson and Kumar (1997) and Næss et al (1995) identify links between car ownership and population density. Higher density areas tend to have lower levels of car ownership. According to evidence from the United States presented by Gordon et al (1989a), car ownership tends to be lower in larger cities. Other studies show that car ownership increases as the distance from the city centre increases (Mogridge, 1985; Næss and Sandberg, 1996).

Flannelly and McLeod (1989) show how the possession of a *driver's licence* is linked to the choice of mode for commuting. People who use the bus are likely to come from households where fewer members have a driver's licence. Interestingly, it is reported that people who share cars to work are likely to come from households with more drivers' licences than average (op. cit.).

Prevedouros and Schofer (1991) report that *work status* does not explain the variation in trip frequency. Ewing et al (1996) report that journey frequency increases as the number of workers per household increases. Ewing (1995) reports that average travel time per person increases as the number of workers per household increases, reflecting the fact that where there is more than one worker in household, home location may not be near to the workplace of each worker.

Hanson (1982) reports no differentiation in total trip frequency by *gender* in Sweden. Gordon et al (1989b) report that the frequency of non-work trips is higher for women than men in the United States and that women have shorter work trips than men regardless of income, occupation, marital and family status.

Hanson (1982) reports no differentiation between trip frequency by *age*, whilst Prevedouros and Schofer (1992) report that trip frequency is age dependent. Evidence from Flannelly and McLeod (1989) suggests that age has no significant effect on the choice of mode for commuting. Næss et al (1995) report that transport energy consumption increases with increasing age. Banister et al (1997) report a negative correlation between the transport energy consumption of an area and the proportion of children resident.

According to Hanson (1982), journey frequency increases as *household size* increases. Evidence from Ewing et al (1996) supports this finding. Ewing (1995) reports that travel time per person increases as household size increases. Banister et al (1997) report that household size is negatively correlated with transport energy consumption.

Evidence from Flannelly and McLeod (1989) suggests that the level of education has no significant effect on the choice of mode for commuting.

Some significant differences in travel patterns are reported according to *attitudes* to various aspects of urban life (Kitamura et al, 1997). It is reported that higher than average trip frequency is associated not just with pro-car attitudes but also rather inconsistently with attitudes which are either pro-environment or pro-public transport/ridesharing. Perhaps unsurprisingly, people with pro-public transport attitudes make more journeys by public transport than other people. People with pro-car attitudes tend to make fewest journeys by public transport and the most journeys by car. People with pro-environment and pro-public transport attitudes make the most non-motorised journeys, whereas people with pro-car attitudes make the fewest non-motorised journeys. Other attitudes to urban life (termed time pressure, urban villager, suburbanite and workaholic) were also investigated by Kitamura et al but there were few large differences in travel patterns according to these other attitudes. Flannelly and McLeod (1989) suggest that the choice of mode for commuting is affected by attitudes to travel such as convenience, reliability, comfort, speed, pleasantness, safety and expense.

Prevedouros (1992) examines the differences in travel patterns according to *personality* types and reports that trip frequency and total distance travelled increases with increasing sociability. Different personality characteristics are associated with different types of home location. The proportion of 'sociable' personalities was higher in urban areas and lower in suburban areas. Urban dwellers were therefore more likely to make more trips and travel further than suburban dwellers.

The various socio-economic characteristics are often interconnected and it is often difficult to separate the effect of one from another. In other words, they are often multicollinear. Household income for example is linked to employment type and working status (whether full-time or part-time; how many members of the household are employed). This may influence car ownership and use. Car ownership and use is also influenced by the possession of a driver's licence, age and gender.

Several studies included in this review do not explicitly recognise that different land use characteristics are associated with different socio-economic characteristics which also have an effect on travel patterns. Consequently they do not attempt to differentiate between the effects of land use characteristics and socio-economic characteristics. Other studies recognise the effect that socio-economic characteristics may have on travel patterns but employ a research method that does not differentiate between the effects of land use characteristics and socio-economic characteristics. ECOTEC (1993) for example recognise the relationship between population density, lifestyles, income and car ownership but do not attempt to identify the separate effects of socio-economic characteristics and land use patterns. They report that:

"*...in Britain, there is a strong relationship between the population density of residential areas and the average income levels of the residents. Lower income levels in high density areas will have implications for both lifestyles and levels of car ownership. This... warns against making simple conclusions about the independent nature of density and, in particular, on the extent to which a policy favouring higher density in new suburban developments will have beneficial effects on travel behaviour. In principle, the effects of density, location and income levels could be separated by a statistical analysis which controls for the latter two variables. However, the necessary data for this analysis are not available. Some of the data which are available suggests that socio-economic factors – and in particular car ownership – are more significant than density per se in explaining inter-personal and inter-area variations in travel behaviour.*"

Several other studies recognise the effect of socio-economic characteristics and employ research methods that attempt to hold socio-economic variables constant in order to observe the effects of land use and characteristics. Many of these studies have been carried out within the last decade. Two methods have been employed to hold socio-economic variables constant.

The first and more popular approach uses multiple regression analysis, in which socio-economic variables and land use characteristics are treated as explanatory variables (examples include: Cervero, 1989; Ewing, 1995; Ewing et al, 1996; Frank and Pivo, 1994; Kitamura et al, 1997; Næss, 1993; Næss et al, 1995; Næss and Sandberg, 1996; Prevedouros and Schofer, 1992). The method allows identification of the main socio-economic and land use characteristics that are associated with certain travel patterns. The method does not however allow the identification of causal relationships (as discussed earlier). A second, less popular method employed to hold socio-economic variables constant involves the selection of case study areas which have similar socio-economic profiles but different land use characteristics. In this way, socio-economic differences are minimised and the variation in travel patterns is assumed to be the result of land use characteristics (examples include Handy, 1992 and Headicar and Curtis, 1994).

Like the interconnection of socio-economic characteristics, it is also likely that a number of land use characteristics are also interlinked (and multicollinear). Settlement size for example may be linked to population density (since large cities are often denser than small, dispersed villages), the distance from the urban centre or the availability of residential parking. Establishing the individual effects of these characteristics from correlation analyses is therefore difficult.

3.4 Summary

A number of land use characteristics from regional to local in scale can affect travel patterns and influence the environmental impacts of transport. Planning policies are therefore a means of promoting more sustainable transport. Land use characteristics can affect travel patterns and influence the environmental impacts of transport by influencing travel demand and/or by influencing modal choice. There is a large amount of literature from around the world on the relationships between land use and travel characteristics. Much of the evidence contained in the review originates in either Western Europe or the United States.

There is broad consensus from these studies about the effects of local facilities and services on travel patterns. The provision of local facilities may overall contribute to less travel overall but might not contribute to any more travel by less energy intensive modes, namely walking and cycling.

There is a growing body of research that suggests a link between population density and many measures of travel patterns. There is little evidence however of much variation in journey frequency by population density. In contrast to the amount of research into the relationship between population density and travel patterns, there has been little recent research concerning the relationships between employment density and travel patterns.

There has been a relatively large amount of research concerning the relationship between settlement size and travel patterns. The relationship between settlement size and travel patterns is unlikely to be simple due to the interplay of competing factors. Evidence from Great Britain shows that large metropolitan settlements are associated with low travel distance and transport energy consumption. Evidence from the ten largest urban areas in the United States however shows no easily identifiable relationship between urban population size and modal choice.

In many studies, increasing distance from home to the urban centre is associated with increasing travel distance, an increasing proportion of car journeys and increasing transport energy consumption. Trip frequency however does not vary significantly according to the distance between home and the urban centre.

There are relatively few studies that have examined the effect of land use mix on travel patterns such as the effect of job ratio. There is little consensus on the effect of land use mix on travel patterns although it is speculated that land use mixing may contribute to lower travel demand, particularly through the decentralisation of less specialised employment.

The proximity to transport networks also influences travel patterns and consequently transport energy consumption. Better access to major transport networks, particularly road and rail networks, increases travel speeds and extends the distance which can be covered in a fixed time. Major transport networks can be a powerful influence on the dispersal of development – both residential and employment development. The proximity to major transport networks may lead to travel patterns characterised by long travel distances and high transport energy consumption.

The availability of residential car parking is linked to both trip frequency and modal choice. As the availability of residential car parking increase, the proportion of car journeys increases.

The limitations of empirical studies include issues of data accuracy, reliability and quality and the applicability of various research methods. Empirical studies do not easily lend themselves to establishing the causality of land use and transport relationships. Socio-economic characteristics often add extra complexity in making comparisons of travel patterns between different areas. The interpretation of results therefore requires a way of differentiating between the effects of land use and socio-economic characteristics on travel patterns. There may be links between socio-economic characteristics and travel patterns as well as between land use characteristics and travel patterns. It is clearly important that the effects of land use and socio-economic characteristics are differentiated in the interpretation of results.

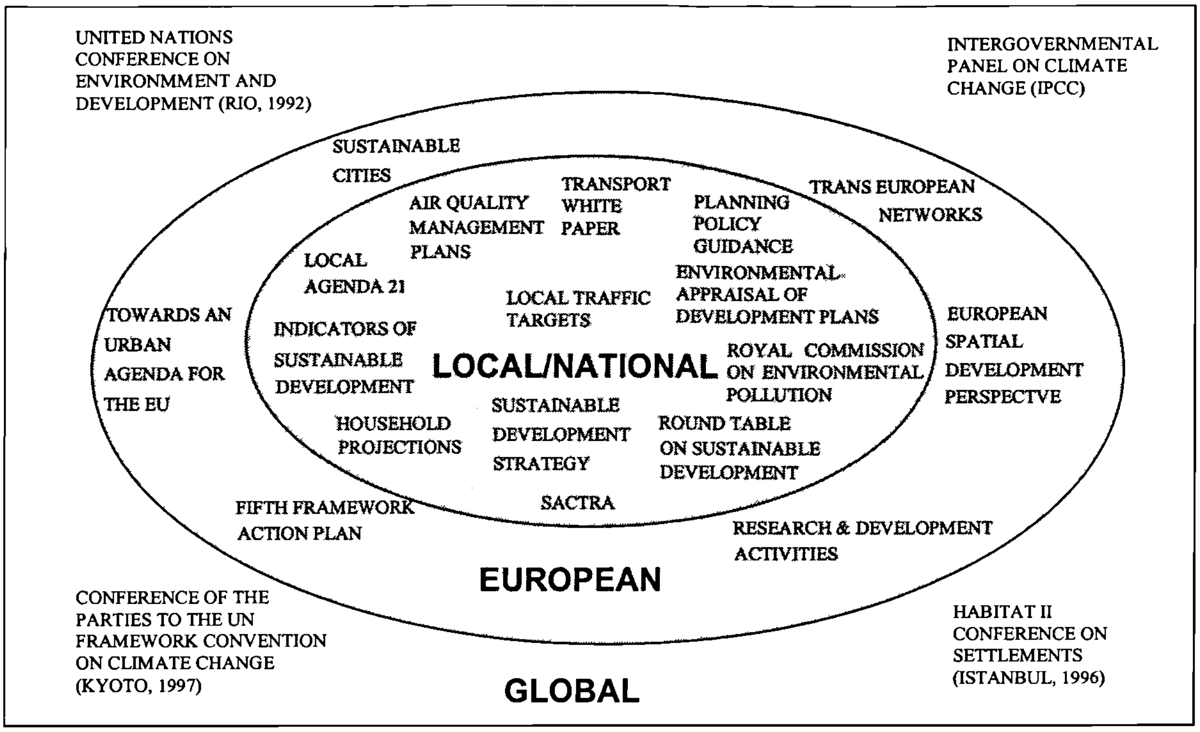
CHAPTER 4: LAND USE AND TRANSPORT PLANNING – THE UNITED KINGDOM POLICY CONTEXT

This chapter sets out the policy context for land use and transport planning in the United Kingdom, focusing particularly on the planning system in England and Wales. The chapter begins by identifying some of the main influences on transport and land use planning in the United Kingdom. It then outlines the planning system in England and Wales and discusses the increasing importance of integrating transport and land use planning. It reviews current land use and transport planning policy guidance particularly in relation to the land use characteristics identified in chapter 3: the distance to the urban centre; settlement size; the mixing of land uses; the density of development; the proximity to main transport networks; and the proximity to local facilities. The chapter shows that there is now increasing emphasis on the integration of transport and land use planning policy and the incorporation of environmental concerns into these policies but identifies a number of areas where further integration is possible.

4.1 THE INFLUENCES ON TRANSPORT AND LAND USE PLANNING IN THE UK

There are a large number of influences on transport and land use planning in the United Kingdom, ranging from influences at the international level (such as agreements on Climate Change made at Rio in 1992) down to influences at the local level (such as local traffic targets made under the 1997 Road Traffic Reduction Act). The different levels of influences on transport and land use planning policy are illustrated in Figure 4.1.

FIGURE 4.1 THE INFLUENCES ON LAND USE AND TRANSPORT PLANNING IN THE UK



Until recently transport policy in the United Kingdom could have been described as demand-led but there is now evidence that this 'predict and provide' approach to transport is being replaced by an approach based on 'new realism', in recognition of the fact that even if new infrastructure were built to accommodate the expected increases in demand, congestion would still worsen as there is a substantial latent demand and that demand will always rise at a faster rate than new facilities can be built (see for example Banister, 1997; Goodwin et al, 1991). It is now widely acknowledged that new roads generate strong development pressures and encourage the decentralisation of population and employment, generating additional traffic, pollution and energy use (see for example Standing Advisory Committee on Trunk Road Appraisal, 1994 or Royal Commission on Environmental Pollution, 1994). According to Banister (1997), there are five stages in the new realism:

(i) consensus that projected traffic growth is not sustainable.

(ii) recognition that road schemes are not going to solve the problem: even if substantial investment does take place, congestion on the road system will worsen since it cannot keep pace with demand.

(iii) discussion about limiting the use of the car and increasing the costs of travel so that demand can be matched to supply.

(iv) awareness that the environmental consequences of unlimited mobility and the problems of congestion mitigate against a continuation of 'predict and provide' policy making.

(v) realisation that the only way to improve both environment and congestion is to use the car less.

Banister (1997) argues that transport policy making has progressed through stages (i) and (ii) in the United Kingdom and is now moving from stage (iii) to (iv).

4.2 THE PLANNING FRAMEWORK

The planning and control of development in England and Wales is operated largely by local planning authorities within a framework set by central government. For these purposes, 'development' is defined in section 55 of the 1990 Town and Country Planning Act as '*the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any building or other land*'.

The Department of the Environment, Transport and the Regions and the Welsh Office issue national policy guidance mainly through a series of Planning Policy Guidance notes (PPGs) in England and Technical Advice Notes (TANs) in Wales. The content of PPGs relating to various land use characteristics is presented in the following section (section 3.2). There is no statutory regional planning system but the Department of Environment issues Regional Planning Guidance notes (RPGs) which are based broadly on advice prepared by groups of local authorities in England[1]. The equivalent in Wales is Strategic Planning Advice prepared by the Welsh Office in response to advice submitted by local authorities.

The process of drawing up Regional Planning Guidance notes is intended to allow the interactions between land use planning and transport infrastructure to be examined so that the guidance itself can promote both their integration and co-ordination. All types of development plan must include land use policies and proposals relating to the development of the transport

1. The procedure for producing Regional Planning Guidance (RPG), as well as the scope, content and form of RPGs is under review. In January 1998, the Department of the Environment, Transport and the Regions issued a consultation paper on the Future of Regional Planning Guidance, outlining a range of options for the reform ofRPGs (Department of the Environment, Transport and the Regions, 1998d).

network and to the management of traffic. They must also include all schemes in the government's trunk road programme.

The 1990 Town and Country Planning Act requires all local planning authorities to prepare and keep up to date a development plan containing policies and proposals relating to the development of the whole of their area. Under the Act, local planning decisions must accord with their development plan unless material considerations indicate otherwise. This advice informs the structure plans prepared by county councils which cover broad land use issues and provide a framework for the local plans in which district councils set out more detailed development policies for their areas. In areas served by single-tier authorities (London and English metropolitan districts for example) two-part unitary development plans fulfil the purposes of structure and local plans.

The United Kingdom Sustainable Development Strategy recognises that the growth in many of the environmental impacts of transport poses a major challenge to the objective of sustainable development but asserts that the coordination of land use planning and transport can make a significant contribution to the goals of sustainable development by reducing reliance on the car (HM Government, 1994). The recent Transport White Paper for the United Kingdom sets out the government's commitment to land use planning and identifies a central role for land use planning in reducing the environmental effects of transport by complementing and contributing to the success of other measures (Department of the Environment, Transport and the Regions, 1998c).

4.3 PLANNING POLICY GUIDANCE

The role of planning policy guidance is to inform local planning authorities about the scope and content of policies to be included in local plans. The general principles of land use planning in England Planning are set out in policy guidance note 1 (PPG1). It outlines the agreements at the Rio Summit on Environment and Development in 1992 which commit the government to the principles of sustainable development in all areas of policy[1]. Reiterating the United Kingdom Strategy for Sustainable Development, PPG1 sets out the importance of

1. The document 'Planning Guidance (Wales) – Planning Policy' sets out the general principles of land use planning in Wales and requires local planning authorities to embrace the concept of sustainable development in all policies within development plans (Welsh Office, 1997).

land use planning in regulating the development and use of land in the public interest and promoting sustainable development (Department of the Environment, 1997b). It sets out four axioms for a planning framework that promotes sustainable development:

(i) providing for "*the nation's needs and industrial development, food production, minerals extraction, new homes and other buildings, while respecting environmental objectives*"

(ii) using "*already developed areas in the most efficient way, while making them more attractive places in which to live and work*"

(iii) conserving "*both the cultural heritage and natural resources (including wildlife, landscape, water, soil and air quality) taking particular care to safeguard designations of national and international importance*"

(iv) shaping "*new development patterns in a way which minimises the need to travel*"

Reducing the need to travel (and minimising the environmental impact of transport) is therefore a key objective for land use policies. PPG1 requires all planning authorities to integrate environmental concerns into all development plan policies. The Department of the Environment's good practice guide for the environmental appraisal of development plans provides guidelines for local planning authorities carrying out environmental appraisal in order to determine whether planning policies accord with national and local environmental objectives (Department of the Environment, 1993).

Planning policy guidance note 13 (PPG13) addresses the coordination of land use planning and transport which the 1998 Transport White Paper describes as "*a major step towards planning land uses and transport together*" (Department of the Environment, Transport and the Regions, 1998c). PPG13 advises local authorities on the use of various types of planning policies to achieve the aims of reducing the need to travel and encouraging less polluting transport choices, thus reducing the environmental impacts of transport[1]. Five types of policies that contribute to the achievement of these aims are identified:

(i) policies that promote development within urban areas at locations highly accessible by means other than the car

(ii) policies that locate major generators of travel demand in existing centres which are highly accessible by means other than the car

1. PPG13 applies only to local planning authorities in England. Similar policy planning guidance for local authorities in Wales is contained in Technical Advice Note 18 (Welsh Office, 1998).

(iii) policies that strengthen existing local centres – in both urban and rural areas – which offer a range of everyday community, shopping and employment opportunities and aim to protect and enhance their viability and vitality

(iv) policies that maintain and improve choice for people to walk, cycle or use public transport rather than drive between homes and facilities which they need to visit regularly

(v) policies that limit parking provision for developments and other on or off-street parking provision to discourage reliance on the car for work and other journeys where there are effective alternatives

Other PPGs also identify ways in which the planning of different types of development (such as retail, industrial and commercial developments) can reduce the need to travel and encourage less polluting transport choices. National and local government are committed to the assessment and management of air quality Under Part IV of the 1995 Environment Act. Environment Circular 15/97 (Department of the Environment, Transport and the Regions, 1997h) introduces a series of guidance notes to assist local authorities in exercising their responsibilities under the Act including notes on air quality and traffic management and another on air quality and land use planning (see section 2.4). These air quality guidance notes generally reinforce the guidance contained within PPGs and add further emphasis to the use of planning measures to tackle the environmental impacts of transport.

Content of planning policy guidance notes that include specific reference to the seven specific land use characteristics[1] identified in the research hypotheses (chapter 1) are reviewed below. The content of some planning policy guidance may soon change however as a result of revisions to the guidance announced in the 1998 Transport White Paper (Department of the Environment, Transport and the Regions, 1998c). The White Paper sets out the government's intention to update the policy planning guidance notes (which apply in England) on housing (PPG3), development plans (PPG12) and transport (PPG13) to ensure "*the right framework to deliver integrated transport policy at the local level*" (Department of the Environment,

1. The seven land use characteristics identified in the research hypotheses (chapter 1) comprise:
   (i) the distance to the urban centre
   (ii) settlement size
   (iii) the mixing of land uses
   (iv) the proximity to local facilities
   (v) the density of development
   (vi) the proximity to main transport networks
   (vii) the availability of residential parking

Transport and the Regions, 1998c). The revised planning guidance on housing will give clearer advice on the location and form of housing development. It will emphasise the benefits of providing new homes in towns and cities and making the most of places which can be well served by public transport or easily reached by foot or bicycle. The revised guidance will stress the need for careful planning of sites that are not close to existing public transport routes to avoid undue reliance on the car. The options available to local planning authorities will include ensuring that any major new development provides good public transport as part of the scheme or, where this is not feasible, using the location for activities that do not generate significant travel demands (ibid.). A fully revised draft planning policy guidance note on development plans is soon to be published. It will draw from the public consultation exercise earlier in 1998 on proposals for improving the procedures for preparing development plans and their content. The guidance will set out the new approach for producing plans more quickly and provide guidance on how development plans will integrate with local transport plans (ibid.). The existing policy planning guidance on transport will be updated for major growth and travel generating uses, with an increased emphasis on accessibility to jobs, leisure and services by foot, bicycle and public transport. This will include the promotion of major developments within public transport corridors and other areas where good public transport exists or can be provided. There will be further guidance on how parking measures can be used to support policies for the location of new development and how land use planning can promote public transport, walking and cycling (ibid.).

4.3.1 Distance from the Urban Centre

It is clear from the literature review (in chapter 3) that the distance to the urban centre may influence travel patterns. Despite several references to maximising the amount of new development in urban areas, planning policy guidance notes contain little detail about the distance between new development and the urban centre and how this may affect travel choices. Planning policy guidance note 6 (PPG6) advocates a sequential approach to the selection of locations for retail development, in which first preference should be given for town centre sites, followed by edge-of-centre sites, district and local centres and then out-of-centre sites that are accessible by a choice of transport modes (Department of the Environment, 1996b). A similar hierarchy is not contained in guidance concerning housing or industrial development however.

4.3.2 Settlement Size

There is little planning guidance concerning settlement size. PPG13 makes brief reference to settlement size, advising that the development of small new settlements – "*broadly those unlikely to reach 10,000 dwellings within 20 years*" – should be avoided, especially "*where they are unlikely to be well served by public transport and are not designed to be capable of being largely self-contained*" (Department of the Environment, 1994). No other planning policy guidance notes explicitly address the issue of settlement size. It is likely that the threshold figure of 10,000 dwellings originates from the ECOTEC report (ECOTEC, 1993), which demonstrates that travel distance is higher in settlements containing fewer than 25,000 residents (using data from the 1985/86 National Travel Survey), which is roughly equivalent to settlements containing fewer than 10,000 residents[1]. Leaving aside the issues of comparing travel patterns in different areas due to socio-economic variations, there are other problems with using National Travel Survey data to examine the issue of settlement size. Some of the categories of settlement size recorded in the National Travel Survey data are very broad and not amenable to further disaggregation. The smallest three categories of settlement size are 0-3,000 residents, 3,000-25,000 residents and 25,000-50,000 residents. Clearly there may be significant differences between the land use and travel characteristics of settlements containing 500 residents and those containing 2,000 residents but the National Travel Survey data does not allow for analysis between them. Similarly, there may be significant differences between the land use and travel characteristics of settlements containing 5,000 residents and those containing 20,000 residents. There is no opportunity to investigate any differences using the data from the National Travel Survey.

4.3.3 The Mixing of Land Uses

PPG1 asserts that mixed-use development can be more sustainable than single-use development and can help create vitality and diversity whilst reducing the need to travel (Department of the Environment, 1997b). PPG4 recognises that it may not be appropriate to separate industry and commerce, especially small-scale developments, from residential development (Department of the Environment, 1992a). The diversity of uses in town centres is recognised in PPG6 as important to vitality and viability (Department of the Environment,

1. Average household size in Great Britain was approximately 2.7 persons per household in 1991 (Central Statistical Office, 1997).

1996b). PPG13 advises that, where feasible, employment and residential uses should be provided as mixed-use development to make it possible to live near work (Department of the Environment, 1994). It directs local planning authorities to provide a balance between employment and housing in both urban and rural areas and at the local and strategic scale. The scale at which this advice about mixed-use applies however is not explicit. It is not clear for example whether employment and population should be balanced at the neighbourhood, city or regional scale or whether the interspersion of employment and residential land uses should be at a very local level (alternate buildings with different land uses for example) or at a wider level (such as at the neighbourhood or city level). Lainton (1996) calls for a more precise definition of mixed-use, arguing that the term is meaningless unless the scale of analysis is clear.

4.3.4 The Provision of Local Facilities

Issues of planning at the neighbourhood scale for local services and facilities are contained within both PPG6 and PPG13. Providing a wide range of facilities at the local neighbourhood level according to PPG13 reduces "*the need for people to use cars to meet their day-to-day needs*", advising planning authorities that housing development should be located "*close to local facilities*" (Department of the Environment, 1994). The closeness for each type of local facilities is not fully elaborated however. In terms of local retail facilities, PPG13 advises local planning authorities to encourage "*local convenience shopping by promoting the location of facilities in local and rural centres*" (ibid.), whilst PPG6 advocates the provision and strengthening of local centres to offer a range of everyday community, shopping and employment facilities (Department of the Environment, 1996b). Local authorities are advised to ensure that small-scale retail and service developments serving local needs in rural areas are promoted wherever possible even where public transport may be lacking. Planning Policy Guidance note 7 (PPG7) concerning countryside planning matters states that the main focus for new development in the countryside should be in areas where employment, housing and other facilities can be provided close together in order to sustain local services and move towards a better balance between employment and housing (Department of the Environment, 1997c). The location of leisure, tourism and recreation facilities should also be based on the principle of local provision where possible. PPG13 directs local authorities to "*maintain and encourage the provision of local leisure and entertainment facilities*" and "*make provision for attractive and accessible local play areas, public open space and other recreational* *facilities*" (Department of the Environment, 1994). The provision of other public facilities such as schools, health centres, branch libraries and local government offices are also considered in PPG13, stating that planning policies should encourage the location of these facilities "*in residential areas or local centres so that they are accessible by foot or by bicycle*" (ibid.). Planning policy guidance does not specify catchment or threshold populations for different types of activities. It is suggested that they may be useful in assisting decisions about the provision of local facilities (Banister, 1996; Barton et al, 1995). PPG13 specifies a range of 'everyday activities' which might be provided locally (Department of the Environment, 1994). These include shops, play areas, open space, schools, health centres, branch libraries and local government offices although different lists have been suggested by other research (by Hillman et al, 1973 and 1976; Hillman and Whalley, 1983; and Winter and Farthing, 1997, for example). Research by Winter and Farthing (1997) suggests that the most regularly-used local facilities include foodshops, newsagents, open space, post offices, primary and secondary schools, pubs and supermarkets.

4.3.5 The Density of Development

PPG13 urges local planning authorities to promote "*higher-density residential development near public transport centres or alongside corridors well served by public transport (or with the potential to be served)*" in order to reduce the need to travel (Department of the Environment, 1994). It also encourages local planning authorities to set standards to maintain existing densities and increase them "where appropriate" although no definitions or examples of appropriate locations or conditions for higher densities are provided. The advice is not specific about the meaning of higher and lower densities, the extent to which they should be increased, or whether there is an optimum density. Planning policy guidance note 3 (PPG3) sets out government advice to local planning authorities on planning residential developments (Department of the Environment, 1992b). It also contains advice on residential densities. Unlike PPG13 however most of the advice on development density is focused on protecting against high densities rather than encouraging them. PPG3 advises that it is "*no longer necessary to insist on packing new houses in at 20 or 30 to the acre*" (approximately 50 to 75 dwellings per hectare) in rural areas (ibid.). It implies that these densities (20-30 houses per acre) in rural areas are aesthetically wrong, giving rise to "*a very urban or "raw" appearance*" (ibid.). One of the few other occasions on which development density is mentioned in PPG3 also focuses on the protection against high densities, advising local planning authorities that they may include policies on density in development plans where the pressure for development or redevelopment might seriously threaten the character of established residential areas. PPG3 contains no guidance on minimum residential densities. A recent survey of local planning authority density standards in England indicates that typical plan-based and 'notional' residential density standards are between 25 and 35 dwellings per hectare (Breheny and Archer, 1998). These standards are generally expressed as maximum allowable values and rarely indicate minimum densities despite the pressure from PPG13 to promote higher densities in certain areas. According to Breheny and Archer (1998), however, plans (and planners) are often unclear whether the density figures refer to net or gross values (whether the area of non-residential development such as roads, retailing, schools and open space, is excluded or included in the density calculation). Breheny and Archer (1998) report that there is little evidence to suggest that the new environmental agenda in planning has introduced a move towards higher densities. A more extensive range of land use density measures (including town or district density, neighbourhood density, gross development density, net site density and net developable site density) is described by Llewelyn-Davies (1998).

4.3.6 The Proximity to Main Transport Networks

PPG13 advises that, wherever possible, housing development should be located in existing larger urban areas where there is a choice of travel modes. Where housing needs cannot be met in such locations, local planning authorities are directed to "*promote land for housing in locations capable of being well served by rail or other public transport*" and to prevent against housing development in locations "*where the travel needs are unlikely to be well served by public transport*" (Department of the Environment, 1994). As for the location of industry and commerce, local planning authorities are advised by PPG13 to focus the opportunities for the development of travel-intensive uses in urban areas that are well served or have the potential to be well served by public transport. Conversely, it states that major industrial and commercial developments should be avoided in "*locations not well served by public transport or otherwise readily accessible to a significant local residential workforce*". The guidance advises that only activities that are not employment-intensive or travel-intensive should be located in areas unlikely to be served by public transport. This advice is echoed in planning policy guidance note 6 (PPG6) concerning town centres and retail developments which states that policies should be adopted to "*locate major generators of travel in existing* *centres, where access by a choice of means of transport, not only by car, is easy and convenient*" (Department of the Environment, 1996b). PPG13 states that the availability of public transport is "*a very important ingredient in determining locational policies designed to reduce for travel by car*" (Department of the Environment, 1994). It advises that rail stations and light rail stops should be the preferred location for travel intensive development. In the case of new retail developments, PPG6 advises local authorities to establish whether public transport will be "*sufficiently frequent, reliable, convenient and come directly into or past the development from a wide catchment area*" (Department of the Environment, 1996b). PPG13 advises that facilities with wide catchments such as certain education and other public facilities should be located so that they are "*well served by public transport and as accessible as possible for those who need to use them*" (Department of the Environment, 1994). It is likely that the greater proximity to major transport networks, particularly road and rail networks, might increase travel speeds and extend the distance that can be covered in a fixed time. Empirical evidence on the subject is lacking (revealed by the review in chapter 3) which may be the reason why this issue is not currently included in planning policy guidance. Neither is any indication of proximity to public transport services suggested in planning guidance. Barton et al (1995) recommend that development should be concentrated (in high-density clusters) within 500 metres from bus and rail stops. The location of development relative to transport infrastructure is more explicit in the Dutch planning system for example, where the accessibility of the location required is determined by the type of development and its accessibility profile (see for example Haq, 1997 or Needham et al, 1993).

4.3.7 The Availability of Residential Parking

PPG13 recognises that the availability of parking has a major influence on the choice of transport mode. It reports that the level of parking provision may be more significant than the level of public transport provision in determining the choice of transport mode even for locations that are very well served by public transport (Department of the Environment, 1994). It recognises that car parking also takes up a large amount of space in developments and reduces densities. PPG13 recommends that parking policies should support the overall location policies of the local development plan and recommends that regional planning guidance sets out strategic parking policies to prevent very different levels of provision between neighbouring planning authorities which can result in excessive development in locations with lower parking standards. The guidance states that local planning authorities should adopt reduced requirements for parking in locations that have good access to alternative means of travel to the car. It states that planning authorities should adopt a flexible approach to the parking requirements for off-street residential parking and reduce or waive them where necessary. It states that local planning authorities should ensure that parking provision at peripheral office, retail and other similar developments is not set at high levels which would significantly disadvantage competition with more central areas. Indicative levels for parking provision in different types of development and in different locations are not outlined in the guidance however.

4.4 CRITIQUE OF CURRENT LAND USE AND TRANSPORT POLICY INTEGRATION

Despite the widespread recognition for the need to integrate transport and land use[1], many argue that integration has yet to happen. The Royal Commission on Environmental Pollution (1997) identifies a number of barriers to the integration of transport and land use despite the introduction of PPG13 (Department of the Environment, 1994) and a guide to better practice (Department of the Environment, 1995). One of the barriers identified by the Royal Commission centres on differences in the level of awareness of PPG13, both within different departments in local government and amongst different types of developers. The Royal Commission report that the understanding of the transport implications of particular patterns of development is limited and identify a need for more guidance on how to implement the policies in practice (even though there is a better practice guide to the implementation of PPG13). Time lags between new policy guidance and the emergence of new policies in development plans are cited as another reason for the lack of integration between transport and land use policies. The Royal Commission also identify an inadequate institutional framework at the national, regional and local level to comprehensively and consistently address transport and land use planning issues.

To address these problems, the Royal Commission propose new forms of assessments on the transport implications to accompany planning applications for major developments, new

1. The need to integrate transport and land use planning is recognised by government and contained within a number of policy documents. These include national statements such as the United Kingdom Strategy on Sustainable Development (HM Government, 1994), the 1998 White Paper on Transport (Department of the Environment, Transport and the Regions, 1998c) and planning policy guidance (PPG13), as well as international documents such as Agenda 21 (United Nations, 1994) and the European Commission's Fifth Environmental Action Plan (Commission of the European Communities, 1995).

institutional arrangements to enable transport and land use to be considered together at all levels (national, regional sub-regional and local) and new requirements for faster changes in development plan policies when guidance and national policy are updated. They also recommend that there should be new institutional arrangements to ensure greater consistency of treatment between different planning authorities, such as the greater use of call-in powers by the Secretary-of-State. Complementary recommendations from the earlier Royal Commission on Environmental Pollution of 1994 include training and education to carry out the tasks required by PPG13, new methods for the assessment of travel implications of land use policies and location decisions and new methods for the assessment of the land use implications of transport policies.

4.5 Summary

There are a large number of influences on transport and land use planning in the United Kingdom, ranging from influences at the international level (such as agreements on Climate Change made at Rio in 1992) down to influences at the local level (such as local traffic targets). The planning system has undergone significant changes over the last decade, resulting in changes to status of plans, the content of planning policy guidance and the role of planning in reducing the need to travel.

Planning policy guidance notes cover a wide range of issues, some of which include specific reference to land use characteristics that may affect travel patterns. Planning policy guidance note 13 (PPG13) is the most important guidance note from the perspective of integrating land use and transport policy. PPG13 asserts that the coordination of land use planning and transport policy can make a significant contribution to the achievement of the United Kingdom's environmental goals (Department of the Environment, 1994).

PPG13 and other planning policy guidance notes address a number of specific land use characteristics relevant to the research hypotheses, such as settlement size, the density of development and the mixing of land uses. Other land use characteristics are either not mentioned or only briefly mentioned. These include the distance from the urban centre and the proximity to the main road network. The guidance notes do not set out detailed information or indicative levels for each of the land use characteristics discussed however.

Many terms in the guidance are unquantified. For example, the scale of mixed uses is not explicit and the precise meaning of terms such as 'close', 'easily reached' and 'high-density' is not elaborated.

There is widespread recognition for the need to integrate transport and land use but full integration has yet to happen. Despite the introduction of PPG13 and a guide to better practice, a number of barriers to the integration of transport and land use remain. There are differences in the level of awareness of PPG13, both within different departments in local government and amongst different types of developers. Understanding of the transport implications of particular patterns of development is limited and more guidance on how to implement the policies in practice is needed. There are commercial pressures on local authorities which mean that authorities do not feel able to be unduly stringent in imposing planning conditions to reduce traffic. Time lags between new policy guidance and the emergence of new policies in development plans are another reason behind the lack of integration between transport and land use policies.

A number of actions are required to integrate land use and transport policy more fully. These include new forms of assessments on the transport implications of developments to accompany planning applications for major developments, new institutional arrangements to enable transport and land use to be considered together at all levels (national, regional sub-regional and local) and new requirements for faster changes in development plan policies when guidance and national policy are updated. Other measures include training and education to carry out the tasks required by PPG13, new methods for the assessment of travel implications of land use policies and location decisions and, conversely, new methods for the assessment of the land use implications of transport policies.

CHAPTER 5: TRAVEL PATTERNS AS ENVIRONMENTAL INDICATORS

This chapter explores the relationship between transport emissions and between various measures of travel patterns. It examines whether the travel patterns within an area can be used to represent trends in vehicle emissions with a view to identifying a useful and simple means of assessing the impact of transport in different location without complex measurements or calculations. This chapter compares calculations of vehicle emissions and energy consumption with various measures of travel patterns using the original data from the 1989/91 National Travel Survey (Department of Transport, 1995b).

Vehicle emissions and energy consumption are dependent on journey distance and a number of different operating conditions such as mode, occupancy, vehicle age, fuel type, engine temperature, travel speed and engine size. The first section of this chapter discusses the way in which these operating conditions affect emissions and energy consumption. The second section shows how journey distance is calculated from National Travel Survey data and describes how vehicle emissions and energy consumption are calculated to take into account the various operating conditions discussed in the first section. Vehicle emissions and energy consumption are then calculated for each journey recorded in the travel survey. Aggregated energy consumption and vehicle emission figures for each person are then calculated. In the third section of the chapter the aggregated energy consumption and vehicle emission figures are then compared using correlation analysis in order to examine the extent to which travel patterns follow similar trends. The energy consumption and vehicle emission are then further aggregated to give average figures per person in each survey area. The figures are then compared with various measures of travel patterns for each area. The extent to which vehicle emissions follow similar trends and extent to which travel patterns can be used to represent trends in vehicle emissions are summarised in the final section of the chapter.

5.1 The Factors Affecting Vehicle Emissions and Energy Consumption

A range of vehicle operating conditions affect emissions and energy consumption. This section discusses how these operating conditions can affect emissions and energy consumption. The operating conditions considered include mode, occupancy, vehicle age, fuel type, engine temperature, travel speed and engine size.

5.1.1 Mode

Table 5.1 shows how vehicle emissions vary by mode. Emissions are related to the vehicle size and fuel type. Buses and coaches generally emit lower volumes of carbon monoxide and hydrocarbons but larger volumes of carbon dioxide and particulate matter relative to those of a medium-sized petrol car. The comparison of emissions presented in the table does not account for the number of passengers typically carried by these different modes. The effect of vehicle occupancy is discussed in the following section.

Table 5.1 Vehicle Emissions Relative to a Medium-sized Petrol Car (without a Three-Way Catalyst)

Vehicle type	Vehicle size/ engine type	Relative emissions per vehicle kilometre (urban conditions)			
		Carbon dioxide (CO_2)	Carbon monoxide (CO)	Hydro-carbons (HC)	Nitrogen oxides (NO_X)
car	petrol, without three way catalyst	1.0	1.0	1.0	1.0
car	petrol, with three way catalyst	1.1	0.4	0.2	0.2
car	diesel	0.9	0.0	0.0	0.3
van	petrol, without three way catalyst	0.9	0.6	0.5	0.8
van	diesel	1.0	0.0	0.1	0.6
goods	diesel, 3.5 - 7.0 tonnes	2.6	0.1	0.2	3.0
minibus	up to 16 seats	1.6	0.1	0.1	1.1
midibus	17-35 seats	2.6	0.1	0.2	3.0
large bus	over 36 seats	5.9	0.6	1.3	7.1
coach	over 36 seats	5.1	0.2	0.2	6.5

Source: Department of Transport (1996a).

5.1.2 Vehicle Occupancy

Vehicle occupancy is clearly an important determinant of emissions and energy consumption per passenger-kilometre. Simple calculations using data from Table 5.1 show that the emissions of carbon dioxide per passenger-kilometre from a medium sized car carrying two passengers are similar to those a minibus carrying three passengers or a coach carrying ten passengers. A similar amount of fuel is required to carry four people in a medium-sized car as six people in a minibus, twelve people in a large bus or one person on a motorcycle. Analysis of data from the 1989/91 National Travel Survey reveals that car occupancy shows some significant variations by journey purpose but that the time of travel has less effect on car occupancy. Potter (1997) reports that there has been a 7 per cent fall in car occupancy between the National Surveys of 1972/73 and 1992/94. The decline has been much greater for some types of journeys such as for commuting and escort trips.

5.1.3 Vehicle Age

According to Anable et al (1997), vehicle age can influence emissions in two ways. Firstly, age is often a surrogate for the general state of maintenance – the older the car, the less well maintained it is likely to be. Secondly, age is related to vehicle technology – newer cars are likely to have more fuel efficient and less polluting features. Thus, as vehicle age increases, emissions and energy consumption are also likely to increase. Potter reports only a small improvement (of 5 per cent) in the energy efficiency of new vehicles between 1970 and 1993. This corresponds with analysis of vehicle efficiency by Sorrell (1992) who reports that the average fuel consumption of new cars decreased through the 1970s until the late 1980s and then increased slightly until 1990. This is partly the consequence of trends towards more powerful and heavier cars which have mitigated against some of the fuel and emission reductions brought about by improvements in vehicle technology.

5.1.4 Fuel Type

Fuel type significantly affects energy consumption and emissions. Under urban conditions (where vehicle speeds are low) a car with a petrol engine and a three-way catalytic converter typically produces more emissions of carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxides than a similarly sized vehicle with a diesel engine (Gover et al, 1994). The diesel car is likely to consume less energy but produce more particulate matter. At higher speeds (such as motorway driving), emissions of carbon dioxide and hydrocarbons are likely to be similar for both petrol and diesel cars. The petrol car is likely to produce more carbon monoxide, whilst the diesel car is likely to produce more nitrogen oxides and particulate matter. Empirical studies suggest that diesel cars may be 20 to 30 per cent more energy efficient in terms of kilometres per litre of fuel than petrol cars of a similar size and specification (Redsell et al, 1988; Eggleston, 1992) which is between 9 and 18 per cent greater energy efficiency in terms of energy consumption per vehicle kilometre[1].

5.1.5 Engine Temperature

Emissions of carbon dioxide, carbon monoxide, hydrocarbons and particulate matter are all higher when the engine temperature is cold (Gover et al, 1994). This is true for both petrol and diesel engines. Fuel efficiency is likely to be of the order of 25 per cent lower under cold conditions. Emissions of carbon monoxide and hydrocarbons from petrol vehicles when operating cold are approximately double the emissions from a hot engine since the catalytic converter does not operate efficiently when cold. High emissions under cold conditions can be expected for the first two miles of the journey (Eggleston et al, 1991). A large proportion of pollutants are emitted under cold conditions for the reasons that a large share of journeys are made by car, most car journeys begin from cold-starts and approximately a quarter of all journeys in Great Britain are under two miles (Department of Environment, Transport and the Regions, 1997e).

5.1.6 Vehicle Speed

There is a non-linear relationship between vehicle speed, pollution emissions and energy consumption. At low speeds, high emission levels and poor energy efficiency are the consequence of inefficient engine conditions. At high speeds, fuel consumption begins to increase as a result of greater wind resistance. Increased energy consumption results in higher emissions. According to Anable et al (1997), cars are usually designed to operate most efficiently at road speeds between 50 and 60 miles per hour for petrol cars and between 40 and 50 miles per hour for diesel cars. A number of studies have examined the effects of

1. The calculations assume that 1 litre of petrol is equivalent to 35.1 MJ and 1 litre of diesel is equivalent to 38.6 MJ (Department of Trade and Industry, 1995).

average vehicle speed on fuel economy (see for example Redsell et al, 1988 or Eggleston, 1992). Redsell et al (1988) report that the energy consumption of petrol cars is lowest when the average vehicle speed is around 65 kilometres per hour.

5.1.7 Engine Size

Vehicle engine size (capacity) is directly related to emissions and energy consumption. Vehicles with larger engines consume more fuel and emit more pollution, particularly carbon dioxide and nitrogen oxides. Calculations by Gover et al (1994) suggest that vehicles with large engines produce at least 50 per cent more emissions of carbon dioxide and nitrogen oxides than vehicles with small engines operated under similar driving conditions. Sorrell (1992) reports a linear relationship between engine size and fuel consumption. There is often however a large difference between the most and least efficient vehicle within each engine size range. For example, the fuel consumption of various petrol cars with a 1.3 litre engine can range from 11.8 to 18.5 kilometres per litre: a difference of 57 per cent. Factors such as turbocharging, fuel injection, vehicle weight and two/four wheel drive are cited as reasons for this large variation. The average engine size of new vehicles increased from 1.40 to 1.54 litres between 1973 and 1992 and the average power output increased by 35 per cent (Royal Commission on Environmental Pollution, 1994) which has mitigated against some of the fuel and emission reductions brought about by improvements in vehicle technology.

5.1.8 Other Factors

Other factors such as driving style, vehicle type and upstream processes also affect emissions and energy consumption (but are not considered in the calculations of vehicle emissions and energy consumption in this study). Driving style, particularly the effects of acceleration, deceleration and overall speed, can have a considerable influence on emissions and energy consumption. It is estimated that between 10 and 15 per cent of fuel could be saved by avoiding rapid acceleration and the inappropriate use of gears (Royal Commission on Environmental Pollution, 1994). Redsell et al (1988) report that 'expert' driving can result in a nine per cent reduction in fuel under urban driving conditions, a ten per cent reduction under suburban driving conditions and a 24 per cent reduction in fuel consumption for motorway driving, compared to the 'typical' driving style. Emissions and energy consumption may vary even when vehicle specifications such as age, fuel type and engine size are similar. There may be differences in emissions and energy consumption between different models of vehicle and between automatic and manual models for example. As well as emissions and energy consumption from vehicle operation, there are also those from upstream processes. These upstream processes include the manufacture of vehicles (including component manufacture and assembly), the construction of transport infrastructure and the processing of fuel from raw materials. The car industry is dependent on energy-intensive industries such as the manufacture of iron and steel. Hughes (1993) estimates that as much as two-thirds of the energy used to produce a car is accounted for by the production of iron and steel. According to Hughes (1993), the total of these upstream impacts may account for up to one-sixth of all energy used in the transport sector and presumably a similar proportion of emissions such as carbon dioxide.

5.2 THE CALCULATION OF VEHICLE EMISSIONS AND ENERGY CONSUMPTION

The starting point for calculating vehicle emissions and energy consumption is the journey distance. The method of calculating journey distance is described in this section. This is followed by a description of the method used to calculate vehicle emissions and transport energy consumption, taking into account the effect of the various operating conditions identified above.

5.2.1 Journey distance

The vehicle emissions and energy consumption of a journey are principally dependent on the journey length: the longer the journey, the more emissions are produced and the more energy is used (under similar operating conditions). Absolute travel distances for each journey are not available from the National Travel Survey data: only a distance category is specified for each journey. It was therefore necessary to obtain special tabulations of mean journey distance for each of the 12 journey categories from the Department of Transport in order to estimate journey distance (Table 5.2). Thus, distance for each journey was determined by the distance category. For example the distance for each journey between 2 and 3 miles in 1989/91 was assumed to be 2.15 miles (since this was the mean distance of all journeys in this category).

Similarly, the distance for each journey between 15 and 25 miles in 1989/91 was assumed to be 18.33 miles.

TABLE 5.2 MEAN DISTANCE FOR EACH NTS JOURNEY DISTANCE CATEGORY

	Mean distance:			
Distance Category	*NTS 1975/76*[1]	*NTS 1985/86*	*NTS 1989/91*	*NTS 1991/93*
0-1 mile	0.51	0.50	0.50	0.50
1-2 miles	1.18	1.12	1.20	1.18
2-3 miles	2.14	2.14	2.15	2.15
3-5 miles	3.51	3.50	3.52	3.53
5-10 miles	6.52	6.49	6.54	6.56
10-15 miles	11.51	11.52	11.57	11.59
15-25 miles	18.17	18.13	18.33	18.38
25-35 miles	26.31	26.32	26.41	26.45
35-50 miles	36.63	37.04	37.10	37.11
50-100 miles	65.63	65.83	66.99	67.10
100-200 miles	133.86	137.03	133.44	134.78
200+ miles	258.67	266.29	280.54	286.17

Source: Department of Transport (1995c).

5.2.2 Vehicle Emissions

The method of calculating emissions uses a set of emission factors for each type of pollutant, derived from the results of on-road vehicle tests in the United Kingdom under different traffic conditions. The emission factors are presented in Table 5.3 and are differentiated according to mode, fuel, vehicle speed, engine size and temperature. The calculations of emissions for each journey recorded in the 1989/91 National Travel Survey were performed using the SPSS statistical package. Emissions of carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides and particulate matter per passenger for each journey were calculated by multiplying the journey distance by the emission factor for each pollutant:

Emissions per passenger (g) = *mode emission factor (g/passenger-kilometre) x journey distance (km)*

1. The Department of Transport was not able produce similar statistics from the 1978/79 National Travel Survey, due to the way in which data were recorded. These averages for each band were used as the measure of distance for each journey. The figures for the 1975/76 National Travel Survey were used as the average journey distances in the analysis of the 1978/79 data.

TABLE 5.3 EMISSION AND ENERGY CONSUMPTION FACTORS BY MODE, FUEL TYPE, ENGINE SIZE, TEMPERATURE AND AVERAGE SPEED

Mode	*Fuel type*	*Engine size*[1]	*Average speed*	*Energy consumption per passenger – km (MJ/pass-km)*[2]	*Emissions per passenger kilometre (g/pass - km)*				
					CO_2	*CO*	*HC*	*NO_X*	*PM*
car[3]	petrol	small	cold	2.16	96	22.15	3.23	1.05	0.07
			0-30mph	1.49	75	10.91	1.31	1.03	0.03
			30-40mph	1.21	66	5.97	0.71	1.09	0.03
			40mph+	1.16	67	2.99	0.41	1.23	0.03
car	petrol	medium	cold	2.47	120	20.08	3.09	1.32	0.07
			0-30mph	1.76	94	9.89	1.25	1.31	0.03
			30-40mph	1.39	78	4.63	0.71	1.36	0.03
			40mph+	1.22	72	2.59	0.41	1.42	0.03
car	petrol	large	cold	3.50	187	20.34	3.06	1.83	0.07
			0-30mph	2.57	146	10.02	1.24	1.81	0.03
			30-40mph	1.80	110	2.28	0.34	1.68	0.03
			40mph+	1.45	90	1.02	0.27	1.51	0.03
car	diesel	small	cold	1.24	83	0.42	0.05	0.26	0.14
			0-30mph	1.03	69	0.30	0.04	0.22	0.07
			30-40mph	0.88	59	0.20	0.03	0.19	0.06
			40mph+	0.84	56	0.15	0.02	0.20	0.05
car	diesel	medium	cold	1.51	101	0.45	0.08	0.42	0.20
			0-30mph	1.26	84	0.31	0.06	0.37	0.10
			30-40mph	1.06	71	0.21	0.04	0.31	0.08
			40mph+	1.02	68	0.16	0.03	0.32	0.06
car	diesel	large	cold	2.04	136	0.49	0.10	0.57	0.21
			0-30mph	1.70	113	0.35	0.08	0.49	0.10
			30-40mph	1.43	96	0.23	0.05	0.42	0.09
			40mph+	1.37	92	0.17	0.03	0.44	0.08
van[4]	all	all	cold	2.73	154	9.76	1.38	1.04	0.27
			0-30mph	2.10	123	4.98	0.79	1.04	0.13
			30-40mph	1.75	105	3.03	0.49	0.91	0.11
			40mph+	1.73	105	2.55	0.34	0.96	0.11
motorcycle[5]	all	all	cold	3.71	165	38.10	5.56	1.80	0.12
			0-30mph	2.57	129	18.77	2.25	1.78	0.06
			30-40mph	2.08	113	10.27	1.22	1.87	0.06
			40mph+	2.00	116	5.14	0.70	2.12	0.06
taxi[6]	all	all	0-30mph	4.03	269	1.20	0.21	1.12	0.53
			30-40mph	3.36	224	0.83	0.16	0.99	0.27
			40mph+	2.24	149	0.40	0.05	0.53	0.13
bus[7]	all	all	0-20mph	1.21	78	0.76	0.24	0.93	0.16
			20mph+	1.03	67	0.37	0.11	0.82	0.12
coach[8]	all	all	0-20mph	0.62	40	0.24	0.03	0.59	0.06
			20-30mph	0.53	34	0.15	0.01	0.56	0.04
			30mph+	0.43	27	0.07	0.01	0.41	0.03
rail[9]	all	all	all	1.60	30	0.36	0.27	1.10	0.15
Underground[9]	all	all	all	1.60	30	0.36	0.27	1.10	0.15

Based on: Gover et al (1994).

1. Small car = 1.4 litres or smaller; medium car = 1.4 to 2.0 litres; large car = larger than 2.0 litres.
2. Figures expressed as Megajoules per passenger kilometre have been converted from the original figures expressed in terms of litres per 1000 kilometres, assuming: i) one litre of petrol is equivalent to 35.1 MJ and 1 litre of diesel is equivalent to 38.6 MJ (Department of Trade and Industry 1995); and ii) an average occupancy of 1.6 persons per car (Potter, 1997).
3. Emissions and energy per passenger kilometre of cars have been calculated assuming 1.6 persons per vehicle.
4. Emissions and energy per passenger kilometre of vans have been calculated assuming 1.5 persons per van.
5. Emissions and energy per passenger kilometre of motorcycles have been calculated assuming 1 person per motorcycle.
6. Emissions and energy per passenger kilometre of taxis have been calculated assuming 0.6 persons per taxi (excluding the driver) and a medium-sized diesel engine.
7. Emissions and energy per passenger kilometre of buses have been calculated by taking the average of three types of bus (minibus, midibus and double-decker) and assuming 20 per cent occupancy.
8. Emissions and energy per passenger kilometre of coaches have been calculated assuming 50 per cent occupancy.
9. Emissions and energy per passenger kilometre for rail and underground calculated from 1990 emissions and energy consumption estimates and rail passenger kilometre figures (Department of the Environment, Transport and the Regions, 1997b and c and Department of Trade and Industry, 1997).

This calculation provides a figure that takes five factors into account, namely mode, fuel, vehicle speed, engine size and temperature. In order to account for two of the other factors that influence emissions and energy consumption (occupancy and vehicle age), the figure was then adjusted using correction factors (see section 5.2.4).

5.2.3 Vehicle energy consumption

Two figures for transport energy consumption are calculated for each journey, termed 'complex' and 'simple' energy consumption. These are described in turn below.

The first calculation of energy consumption, termed *'complex' energy consumption*, is calculated in a similar way to the calculation of emissions, where energy consumption per passenger for each journey is calculated by multiplying the journey distance by the energy consumption factor, derived from the results of on-road vehicle testing in the United Kingdom under different traffic conditions (shown in Table 5.2). As with the calculation of emissions, the energy consumption figure is then adjusted to account for two other factors that influence energy consumption (vehicle occupancy and age) using correction factors presented below. Thus, the calculation of 'complex' energy consumption takes account of mode, fuel type, engine size, engine temperature, average speed, occupancy and vehicle age.

The other method for calculating energy consumption, which provides a second value of energy consumption (*'simple' energy consumption*), only takes into account the journey distance and mode of transport used and uses just one typical energy consumption factor for each mode. The energy consumption factors used to calculate the 'simple' value of energy consumption are presented in Table 5.4. These figures are derived from a review of literature sources and comparison with national energy statistics (see Appendix 1). The 'simple method' does not account for factors such as vehicle speed, fuel, engine size, engine temperature, occupancy and vehicle age.

TABLE 5.4 TYPICAL ENERGY CONSUMPTION FACTORS BY MODE

Mode	*Typical energy consumption (MJ/passenger-kilometre)*
car	1.96
stage bus	1.28
express bus	0.79
rail	1.65
underground	1.55
van/lorry	2.94
walk	0.16
motorcycle	0.99
cycle	0.06
taxi	2.94

Source: Table A1.5 (Appendix 1).

The 'simple' and 'complex' energy consumption figures are used to check the consistency of the two calculations and to examine whether the results of the 'simple method' can be used as an indicator of energy consumption without resorting to the 'complex method' which requires information about vehicle speed, engine size, engine temperature, occupancy and vehicle age for each journey.

5.2.4 Correction Factors

The variations in vehicle occupancies by journey purpose are used to adjust the calculations of emissions and energy consumption. Examination of data from the 1989/91 National Travel Survey data indicates that there is little variation in car occupancy during the day[1] but that there are significant differences in car occupancy by journey purpose. Average car occupancies by journey purpose are presented in Table 5.5. Correction factors are applied to all car journeys to account for these differences in vehicle occupancy. The correction factor is calculated from the ratio of the overall car occupancy rate and the car occupancy rate for the journey purpose. For example, the occupancy correction factor for commuting journeys is 1.45 (equal to 1.72 / 1.19). In other words, lower than average car occupancy for commuting journeys results in 1.45 times more emissions per passenger-kilometre and 1.45 more energy

1. Car occupancy is calculated from the ratio of the number of journeys made by both car passengers and car drivers to the number of journeys made by car drivers:

car occupancy (persons per car) = (journeys by car passengers + journeys by car drivers) / (journeys made by car drivers).

consumed per passenger-kilometre than the average journey. The occupancy correction factor for holiday journeys, on the other hand, is 0.65 (equal to 1.72 / 2.66). Typical holiday journeys produce approximately two-thirds of emissions per passenger-kilometre than the average journey and consume around two-thirds of the energy per passenger-kilometre compared to the average journey since car occupancy is higher than average.

TABLE 5.5 CAR OCCUPANCY RATES AND CORRECTION FACTORS BY JOURNEY PURPOSE

Journey purpose	*Average car occupancy (persons per vehicle)*	*Correction factor*
Commuting	1.19	1.45
Business/work/education	1.22	1.43
Escort to education	2.20	0.78
Other escort	2.10	0.82
Shopping	1.87	0.92
Holiday/day trip	2.66	0.65
Other leisure	2.05	0.84
All purposes	1.72	1.00

Based on: Potter (1997).

The emissions and energy consumption factors presented in Table 5.2 (above) refer to vehicles produced around 1990. According to government statistics, the energy consumption of cars produced before 1980 is of the order of 5 per cent higher than those produced around 1990 (Department of the Environment, Transport and the Regions, 1997b). Emissions from older vehicles are also likely to be higher by a similar order of magnitude. In this study a correction factor is used to account for the difference in emissions and energy consumption due to the age of the car used for each journey. To determine the age of the vehicle used for each journey it is assumed that the household's own vehicle is used for each car journey (the same assumption used earlier to identify the engine size and fuel type). Where the household owns more than one car the average age of all cars in the household is used determine which correction factor for vehicle age to use. In the case of car journeys made by residents of households without a car, the car used is assumed to be newer than a 1985 model. These vehicle age correction factors apply a 2.5 per cent higher rate of emissions and energy consumption to cars made between 1980 and 1985 and a 5 per cent higher rate of emissions and energy consumption to cars made prior to 1980 (Table 5.6).

TABLE 5.6 VEHICLE AGE CORRECTION FACTORS

Vehicle age	*Correction factor*
post-1985	1.000
1980-1985	1.025
pre-1980	1.050

5.2.5 Other Assumptions

To determine the vehicle engine size for each journey it is assumed that the household's own vehicle is used for each car journey. In cases where households had more than one car, the average engine size of all cars in the household is used determine which emission and energy consumption factors to use. In cases where the residents of households without a car made car journeys, the car used for the journey is assumed to be a medium-sized car (1.4 - 2.0 litres).

To determine the vehicle fuel type for each journey it was assumed that the household's own vehicle is used for each car journey. In cases where households had more than one car, the fuel type is assumed to be petrol unless more than half the vehicles in the household were diesel. In cases where the residents of households without a car made car journeys, the car used for the journey is assumed to be a petrol car.

All car and van journeys are assumed to start from cold. Emissions and energy consumption for the first two miles of all journeys by car or van are calculated using 'cold-start' factors. The emissions and energy consumption for the remaining part of the journey are calculated according to the average journey speed. 'Hot' operating conditions are assumed for all journeys by public transport (bus and rail) and by taxi.

5.3 A COMPARISON OF VEHICLE EMISSIONS, ENERGY CONSUMPTION AND TRAVEL PATTERNS

Having calculated energy consumption and vehicle emission figures for each journey, aggregated figures for each person are calculated. These aggregate figures are compared with each other using correlation analysis in order to examine the extent to which they follow similar trends. The energy consumption and vehicle emission are then aggregated again to give average figures per person in each survey area. The figures are compared with various measures of travel patterns for each area to examine the extent to which travel patterns represent trends in vehicle emissions.

5.3.1 Comparison of vehicle emissions and energy consumption

After calculating energy consumption and vehicle emission figures for each journey, aggregated figures for each person are calculated. Table 5.7 presents a comparison of the correlation coefficients between emissions and energy consumption for over 30,000 persons, aggregated from more than 500,000 journeys. Most emissions are highly correlated with others. The two values of energy consumption are very strongly correlated. Transport energy consumption is well correlated with most types of pollutant, particularly carbon dioxide and nitrogen oxides. Particulate emissions are the least well correlated with other types of pollutant, particularly with carbon monoxide and hydrocarbons.

5.3.2 Comparison of vehicle emissions, energy consumption and travel patterns

After aggregating the energy consumption and vehicle emission figures to give an average per person in each survey area, the figures are then compared with various measures of travel patterns for each area to examine the extent to which travel patterns represent trends in vehicle emissions. The travel patterns examined include measures of journey distance, journey frequency, travel time, modal share and transport energy consumption (Table 5.8).

Table 5.9 presents the results of the correlation analysis of these measures of travel patterns with per capita emissions of carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides and particulate matter. The results of the correlation analysis show that some of the measures of travel patterns are quite representative of atmospheric pollutants whilst others are not. Transport energy consumption is the most representative measure of travel patterns to indicate the atmospheric emissions from transport. The complex calculation of energy consumption (which takes into account the vehicle age, fuel type, engine size, engine temperature, travel speed and vehicle occupancy) is more representative of emissions than the simple calculation of energy consumption as would be expected. As indicators of transport emissions, however, there is very little difference between the simple calculation of energy consumption and travel distance.

TABLE 5.7 PEARSON CORRELATION COEFFICIENTS BETWEEN TRANSPORT EMISSIONS AND ENERGY CONSUMPTION[1]

	Energy use per person: 'complex method'[2]	*Energy use per person: 'simple method'*[1]	*Carbon dioxide (CO_2) emissions per person*	*Carbon monoxide (CO) emissions per person*	*Hydro-carbon (HC) emissions per person*	*Nitrogen oxides (NO_X) emissions per person*	*Particulat e matter (PM) emissions per person*
Energy use per person: 'complex method' [2]	1.00	0.94	0.97	0.78	0.81	0.96	0.82
Energy use per person: 'simple method' [3]	0.94	1.00	0.93	0.71	0.74	0.91	0.80
CO_2 emissions per person	0.97	0.93	1.00	0.76	0.78	0.94	0.75
CO emissions per person	0.78	0.71	0.76	1.00	1.00	0.77	0.39
HC emissions per person	0.81	0.74	0.78	1.00	1.00	0.81	0.46
NO_X emissions per person	0.96	0.91	0.94	0.77	0.81	1.00	0.72
PM emissions per person	0.82	0.80	0.75	0.39	0.46	0.72	1.00

Source: Department of Transport (1995b).

TABLE 5.8 MEASURES OF TRAVEL PATTERNS EXAMINED

Type of travel pattern	*Travel pattern examined*
1. Journey distance:	• Travel distance by all modes • Total work distance by all modes • Total non-work distance by all modes • Travel distance by car • Average journey distance
2. Journey frequency:	• Number of journeys by all modes • Number of journeys by car • Number of journeys by public transport • Number of journeys by foot • Number of journeys by cycle
3. Travel time:	• Travel time by all modes • Travel time by car • Average journey time
4. Modal share:	• proportion of journeys made by car • proportion of journeys made by public transport • proportion of journeys made by foot • proportion of journeys made by cycle
5. Transport energy consumption	• Energy use – 'complex method' • Energy use – 'simple method'

1. The table summarises the correlation analysis of more than 500,000 journeys aggregated per person (approximately 30,000 persons) using the 1989/91 National travel Survey data. All values are significant at the 99 per cent confidence level.

2. The complex energy use calculation takes into account the vehicle age, fuel type, engine size, engine temperature (hot or cold operation) travel speed and vehicle occupancy.

Measures of travel patterns such as the travel distance by car, the travel time by car, the total non-work distance by all modes and the travel time by all modes are all reasonable indicators of transport emissions but are less representative than transport energy use or travel distance. These four measures do not correlate so well with emissions of particulate matter.

Measures of travel patterns such as total work distance by all modes, the number of journeys by car and the average journey distance by all modes are not such good indicators of transport emissions whilst the remaining measures of travel patterns identified in Table 5.8 are even poorer indicators of transport emissions[2].

5.4 SUMMARY

This chapter has explored the relationship between transport emissions and the relationship between various measures of travel patterns. It has examined whether the travel patterns within an area can be used to represent trends in vehicle emissions using data from the 1989/91National Travel Survey. The chapter has identified the way in which vehicle operating conditions affect emissions and energy consumption. It has described how vehicle emissions and energy consumption can be calculated to take account of various operating conditions. Vehicle emissions and energy consumption were calculated using data from the 1989/91 National Travel Survey. Energy consumption and vehicle emission figures were then compared with each other using correlation analysis in order to examine the extent to which travel patterns follow similar trends. The energy consumption and vehicle emission were then compared with various measures of travel patterns for each area using correlation analysis to examine the extent to which travel patterns can be used to represent trends in vehicle emissions.

---

1. The simple energy use calculation is the product of journey distance and the typical energy consumption of the mode of transport used.

2. The remaining measures of travel patterns are:
   - average journey time by all modes
   - percentage of journeys made by car
   - the number of journeys by all modes
   - the number of journeys by cycle
   - the percentage of journeys made by cycle
   - the number of journeys by public transport
   - the percentage of journeys made by public transport
   - the number of journeys by foot
   - the percentage of journeys made by foot

TABLE 5.9 PEARSON CORRELATION COEFFICIENTS BETWEEN TRANSPORT EMISSIONS AND VARIOUS MEASURES OF TRAVEL PATTERNS[1]

	Carbon dioxide (CO_2) emissions per person	*Carbon monoxide (CO) emissions per person*	*Hydro-carbons (HC) emissions per person*	*Nitrogen oxides (NO_X) emissions per person*	*Particulate matter (PM) emissions per person*
Energy use per person – 'complex method' [2]	0.97	0.78	0.81	0.96	0.82
Energy use per person – 'simple method' [3]	0.93	0.71	0.74	0.91	0.80
Travel distance per person by all modes	0.91	0.70	0.73	0.92	0.81
Travel distance per person by car	0.81	0.78	0.78	0.83	0.43
Travel time per person by car	0.71	0.82	0.81	0.69	0.35
Total non-work distance per person by all modes	0.76	0.57	0.59	0.77	0.66
Travel time per person by all modes	0.70	0.62	0.64	0.68	0.64
Total work distance per person by all modes	0.59	0.48	0.50	0.59	0.56
Number of journeys per person by car	0.42	0.65	0.65	0.39	0.16
Average journey distance per person by all modes	0.50	0.30	0.32	0.53	0.50
Average journey time per person by all modes	0.39	0.23	0.24	0.40	0.43
Proportion of journeys made per person by car	0.30	0.50	0.50	0.29	0.03
Number of journeys per person by all modes	0.23	0.32	0.33	0.20	0.16
Number of journeys per person by cycle	-0.06	-0.07	-0.07	-0.05	-0.04
Proportion of journeys made per person by cycle	-0.08	-0.09	-0.09	-0.07	-0.05
Number of journeys per person by public transport	-0.11	-0.27	-0.24	-0.06	0.19
Proportion of journeys per person made by public transport	-0.16	-0.31	-0.29	-0.12	0.09
Number of journeys per person by foot	-0.17	-0.20	-0.20	-0.15	-0.12
Proportion of journeys per person made by foot	-0.28	-0.33	-0.34	-0.25	-0.20

Source: Department of Transport (1995b).

The analysis suggests that the 'simple' calculation of energy consumption (which takes account of mode and distance) is very similar to the 'complex' calculation of energy consumption (which also takes account of a range operating conditions including occupancy, vehicle age, fuel type, engine temperature, travel speed and engine size). Energy consumption is a reasonable indicator of most atmospheric pollutants.

1. The table summarises the correlation analysis of more than 500,000 journeys aggregated per person (approximately 30,000 persons) using 1989/91 National Travel Survey data. All values are significant at the 99 per cent confidence level.
2. The complex energy use calculation takes into account the vehicle age, fuel type, engine size, engine temperature (hot or cold operation) travel speed and vehicle occupancy.
3. The simple energy use calculation is the product of journey distance and the typical energy consumption of the mode of transport used.

The most representative measures of travel patterns to indicate the atmospheric emissions from transport are transport energy consumption and travel distance. Measures of travel patterns such as the travel distance by car, the travel time by car, the total non-work distance by all modes and the travel time by all modes are all reasonable indicators of transport emissions but are less representative than transport energy use or travel distance. Measures of travel patterns such as total work distance by all modes, the number of journeys by car and the average journey distance by all modes are less adequate indicators of transport emissions. Other measures of travel patterns examined are poor indicators of transport emissions.

Travel distance per person is a simple and readily available indicator of the atmospheric environmental impacts of transport. Travel distance may not be an accurate indicator of some of the other main impacts of transport such as community severance or noise and vibration although the trends in these impacts may follow the same direction as the trends in travel distance.

CHAPTER 6: CONCEPTUAL FRAMEWORK AND RESEARCH METHODS

Having established the usefulness of different measures of travel patterns as environmental indicators of transport, this chapter sets out how the indicators are used in the study to determine links between land use, travel patterns and environmental impacts. This chapter is divided into three main sections. The conceptual framework of the study is presented in the first section. The research methods used in the study are set out in the second section. The third section examines the strengths and weaknesses of the approach.

6.1 THE CONCEPTUAL FRAMEWORK

The review of research in chapter 3 has identified evidence for a number of relationships between land use characteristics and travel patterns. One of the criticisms of many studies is the omission of socio-economic characteristics from the analysis which may also affect travel patterns. What is clear from the review of research concerning land use and travel patterns is that both land use and socio-economic characteristics have often not been considered together. Only a limited number of socio-economic and land use characteristics have been examined in the few studies where they have been considered together. Most studies that have examined the links between land use planning and travel patterns have excluded the links between socio-economic characteristics on travel patterns (Figure 6.1). Similarly, many studies concerned with the links between socio-economic characteristics and travel patterns have excluded the links between land use characteristics on travel patterns.

This study considers the links between land use, socio-economic characteristics and travel patterns. The starting point for this study is a set of relationships in which socio-economic and land use characteristics are interlinked with each other and interlinked with travel patterns. Furthermore, the interactions between socio-economic characteristics, land use characteristics and travel patterns are two-way, where cause and effect are mutable. Some studies have recognised that both land use and socio-economic characteristics (including demographic characteristics) may influence travel patterns (ECOTEC 1993, Banister et al, 1997 and Breheny 1995 for example) but the links between land use, socio-economic characteristics and travel patterns have largely been under-investigated. This study contends that there is an interaction between land use, socio-economic characteristics and travel patterns as illustrated in Figure 6.2.

FIGURE 6.1 THE RELATIONSHIP BETWEEN TRAVEL PATTERNS AND LAND USE CHARACTERISTICS

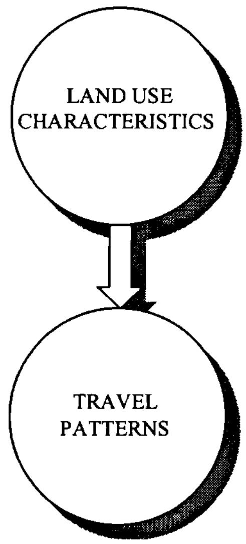
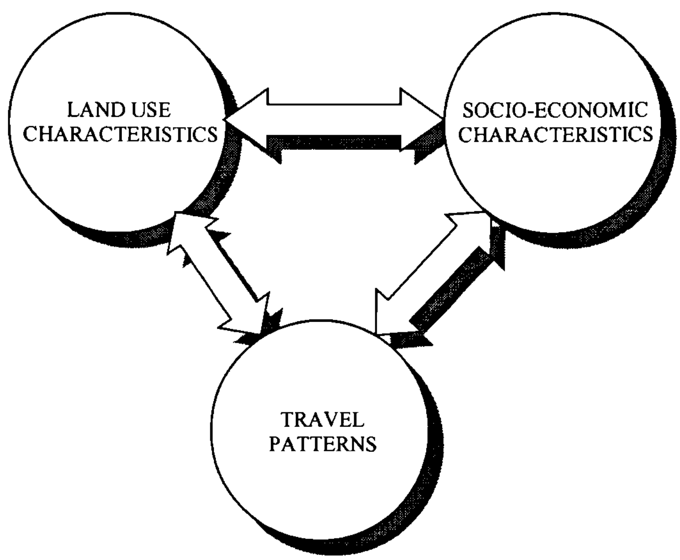


FIGURE 6.2 THE RELATIONSHIP BETWEEN TRAVEL PATTERNS, LAND USE AND SOCIO-ECONOMIC CHARACTERISTICS



Woolley and Young (1994) discuss some of the direct and indirect interactions between land use and travel patterns. They identify how land use may affect environmental quality and hence travel patterns and conversely how travel patterns may affect environmental quality and hence land use patterns (Table 6.1). High car ownership and use within an area may for example increase the demand for new development with wider roads, more parking and located near main road infrastructure. Areas where travel patterns are more orientated towards cycle use or walking may on the other hand encourage higher density developments with little or no car parking. Thus, travel patterns may influence the land use characteristics of new development.

TABLE 6.1 RELATIONSHIPS BETWEEN TRAVEL PATTERNS, LAND USE AND ENVIRONMENTAL QUALITY

Effect → *Cause ↓*	*Travel patterns*	*Land use*	*Environmental quality*
Travel patterns		• Traffic levels may influence the land use characteristics of new development (e.g. road layout, parking provision, density, location)	• Changes in traffic levels lead to changes in environmental quality (air quality, safety, noise, visual intrusion, etc.) • Decreases in traffic speed may increase energy use and air pollution • Modal split may also affect energy use, air quality and noise levels
Land use	• Changes in land use (e.g. settlement size, density and local facilities) may affect travel patterns (see chapter 3)		• Land use patterns may affect travel patterns and hence affect environmental quality
Environmental quality	• Pleasant, safe, unpolluted environments may encourage certain modes (e.g. walking and cycling) • Poor air quality may reduce the attractiveness of some modes (e.g. walking and cycling) • Environmental quality may affect land use patterns and therefore travel patterns	• Good environmental quality may stimulate new development and affect land use patterns • Poor environmental quality may discourage new development and encourage relocation elsewhere, thereby affecting land use patterns	

Based on: Woolley and Young (1994).

6.2 THE RESEARCH METHODS

This study is cross-sectional and does not therefore offer the possibility to identify whether the variations in travel distance are the result of direct or indirect relationships with land use characteristics. The study does however allow exploration of the interactions between land use, socio-economic characteristics and travel patterns in order to substantiate these interactions. The study identifies associations between land use, socio-economic characteristics and travel patterns, from which other work may be able to establish causal links (the study cannot positively identify causality since it is not longitudinal). The study is able to examine the temporal stability of relationships between land use, socio-economic characteristics and travel patterns by comparing data across a time period of more than a decade (using data from National Travel Surveys of 1978/79, 1985/86, 1989/91 and 1991/93).

Analysis of data across a time series also allows for the consistency of relationships between land use, socio-economic characteristics and travel patterns to be examined. The use of local transport data from Kent and Leicestershire provides another means of validating the results from the national travel data and provides a way of examining other links between land use characteristics and travel patterns. The exploration of these interactions provides better understanding of the extent to which both socio-economic and land use characteristics might affect travel patterns. The use of both socio-economic and land use characteristics in the study increases the complexity of analysis but improves understanding of the interactions.

Travel distance is used as the principle measure of travel patterns in subsequent stages of this study since it is was established in chapter 5 as a reasonable proxy for transport emissions and energy consumption. Several sets of data and a number of analytical techniques are used in order to explore the relationships between socio-economic characteristics, land use and travel distance. Two types of data set are examined: data from National Travel Surveys and data from two travel surveys carried out in Kent and Leicestershire. The Data Archive at the University of Essex provided the National Travel Survey data. Kent County Council and Leicestershire County Council provided the local survey data.

Multiple regression analysis is used to examine the relationships between land use, socio-economic characteristics and travel distance (see section 6.2.2). Residual analysis is used in conjunction with interviews to establish additional socio-economic and land use characteristics that may influence travel patterns (see sections 6.2.3 and 6.2.4).

Data from the National Travel Surveys allow extensive examination of the relationships between travel distance and socio-economic characteristics since a large amount of socio-economic data was collected in each of these surveys. Only a limited amount of land use data was recorded in these surveys however which does not therefore allow for very detailed analysis of the relationships between travel distance and land use characteristics. The land use characteristics recorded include urban population size, local authority population density and the proximity to rail and bus services and local population density. It is not possible to supplement the data with additional land use information for each of the areas surveyed for the National Travel Survey since the data are recorded in an anonymous format. The local surveys on the other hand contain only a limited amount of socio-economic data but it is possible to establish much more information about land use characteristics for the survey areas. Thus, the two types of surveys (national and local) are complementary and provide a detailed way of analysing the relationships between travel distance and socio-economic and land use characteristics. The National Travel Survey data are particularly useful for the examination of socio-economic characteristics and also for examining changes in the relationships between travel distance and socio-economic characteristics over time. The two main advantages in examining data from the local surveys are the availability of more extensive land use data and more recent data. Both local travel surveys were carried out in 1995 whereas the most recent data set available from the National Travel Survey is 1991/93[1]. The data allow for analysis of the interaction between socio-economic characteristics, land use and travel distance and also allow for the analysis of these relationships over time. The various land use characteristics examined using the data from the national and local travel surveys are shown in Table 6.2.

1. National Travel Survey data are deposited with the Data Archive after a more recent survey has been collected analysed and reported. After depositing the data at the Data Archive, it takes several months before being available to the public. The data set from the 1991/93 National Travel Survey, for example, was not made available until October 1995.

TABLE 6.2 LAND USE CHARACTERISTICS EXAMINED IN THIS STUDY

Land Use Characteristics	*National Travel Data*	*Local Travel Data (Kent and Leicestershire)*
1. Distance from the Urban Centre	✓	
2. Settlement Size	✓	
3. Mixing of Land Uses		✓
4. Provision of Local Facilities	✓	
5. Density of Development:		
• Local Authority-Level	✓	
• Ward-Level	✓	✓
6. Proximity to the Main Transport Network:		
• Main Road Network		✓
• Railway Station	✓	✓
7. Availability of Residential Parking		✓ (Kent only)

The research employs both a deductive and inductive approach. The analysis of National Travel Survey data is mainly deductive: testing the relationships between travel patterns, socio-economic characteristics and land use characteristics identified in other studies. The analysis of the local travel data is both deductive and inductive. The relationships between travel patterns, socio-economic characteristics and land use characteristics identified in other studies are first tested and the relationships are compared to those found in the analysis of the National Travel Survey data. Secondly, the differences between predicted and observed values of travel distance are calculated and possible explanations for differences are identified (Table 6.3).

TABLE 6.3 RESEARCH APPROACH FOR THE ANALYSIS OF NATIONAL AND LOCAL DATA

Analysis of National travel Survey Data	*Analysis of Local Data (Kent and Leicestershire)*
Deductive – analysing and testing the relationships identified in other studies and testing research hypotheses.	**Deductive** – analysing the relationships identified in other studies and in the analysis of National Travel Survey data and testing research hypotheses.
	Inductive – identifying other land use and socio-economic characteristics that may affect travel patterns where there are significant differences between observed and predicted values of travel distance.

Although travel distance is a reasonable proxy for transport energy consumption and emissions such as carbon dioxide and nitrogen oxides, the use of travel distance as an environmental indicator of transport does not illustrate the distribution and dispersion of transport pollutants within a neighbourhood, city or region. This would require more detailed information about journey times and routes as well as topographical and climatic data. Travel distance is not an accurate indicator of some of the other main impacts of transport such as congestion, community severance or noise and vibration although the trends in these impacts are most likely to follow the same direction as the trends in travel distance.

Data from the National Travel Surveys of 1979/81, 1985/86, 1989/91 and 1991/93 are analysed in order to explore relationships between travel distance and socio-economic characteristics. Variables which might have some influence on travel distance are selected from the large number of socio-economic characteristics collected as part of this survey on the basis of the relationships between socio-economic characteristics and travel patterns identified in chapter 3. These variables are then used in multiple regression analysis in order to establish the main key socio-economic variables that explain the variation in travel distance (see section 6.2.2 for a description of regression analysis). The analysis of the four National Travel Survey data sets allows the relationship between travel distance and socio-economic variables to be examined over time.

A similar process is repeated using the data from the local travel surveys. The key socio-economic variables identified from the analysis of the National Travel Survey data are used in similar regression analyses in order to test their relationship with travel distance at the local level. Regression analysis is then carried out which included both land use and socio-economic characteristics. The regression equation is then used to calculate predicted values of travel distance in the survey wards in Kent and Leicestershire. Residual analysis is then used in conjunction with interviews to identify other socio-economic and land use characteristics that may influence travel patterns (see sections 6.2.3 and 6.2.4).

6.2.2 Multiple Regression Analysis

In a causal relationship between two or more variables the *dependent* variable is influenced by the value of one or more *independent* variables. In this study travel distance is the dependent variable and various socio-economic and land use variables are the independent variables (the independent variables are those that influence the value of the dependent variable).

Multiple regression is a predictive and modelling technique that allows examination of the causal relationship between two or more variables. It can be used to predict and explain the variation of a dependent variable from a number of independent variables or predictor terms. The general multiple regression equation is:

$$Y \qquad = a + b_1X_1 + b_2X_2 + \ldots.\ b_jX_j \pm e \qquad (1)$$

where:

Y	= dependent variable	
a	= intercept value	
b_1 to b_j	= partial regression coefficients	
X_1 to X_j	= independent variables (predictor terms)	
e	= error term	

The partial regression coefficients depend on the units of the independent and dependent variables, the Y and X terms respectively. Partial regression coefficients cannot be directly compared since a larger value does not necessarily imply more importance or significance. Direct comparison of the importance of the independent variables is more appropriately made using *beta weights* which can be regarded as 'standardised' partial regression coefficients. The greater the numerical value of the beta weight (either positive or negative), the greater its importance in accounting for the behaviour of the independent variable.

$$B_i \qquad = b_i\,(s_{xi} / s_y) \qquad (2)$$

where:

B_i	= beta weight
b_i	= partial regression coefficient
s_{xi}	= standard deviation of the independent variable
s_y	= standard deviation of the dependent variable

The explanatory power of the regression equation can be identified using the multiple coefficient of explanation (R^2) which is obtained from the equation:

$$R^2 \qquad = \Sigma(Y_{predicted} - Y_{mean})^2 \ / \ \Sigma(Y_{observed} - Y_{mean})^2 \qquad (3)$$

where:

R^2	= multiple coefficient of explanation
$Y_{predicted}$	= predicted value of the dependent variable obtained from the regression equation
Y_{mean}	= mean of the observed values of the dependent variable
$Y_{observed}$	= observed value of the dependent variable

6.2.3 Residual Analysis

Residual analysis is an established method of geographical analysis (see Shaw and Wheeler, 1994 for example). The study of residuals may direct the research towards other variables that may explain the variation in the dependent variable. Thomas (1968) highlights three main uses of residual analysis for spatial applications:

(i) the formation and modification of hypotheses concerning the spatial association of variables and the search for new variables

(ii) the establishment of regional boundaries and units

(iii) the identification of specific areas for intensive study and further investigation

In this study residual analysis is mainly used for the identification of specific areas for more intensive study and further investigation. Thomas (1968) identifies four types of residuals that can be used in residual analysis: the basic residual, the standardised residual, the ratio of estimated to observed dependent variable and the relative residual. These are described in turn below.

The *basic residual* is the difference between the observed and predicted values of the dependent variable (equation 4). It is an absolute value and expressed in the same units as the dependent variable. Thus, where the dependent variable is travel distance per person per week the residual is expressed in the same units. Residuals of this type can take both positive and negative values. The value of the basic residual is negative where the observed value of the dependent variable is greater than the predicted value whereas the value of the basic residual is positive where the observed value of the dependent variable is less than the predicted value. Maps of the basic residual may be particularly useful where they can be compared directly with the spatial distribution of other phenomena supposed to influence the dependent variable. The comparison of maps may lead to the formulation of more refined hypotheses.

$$\textit{Basic residual} = (Y_{observed} - Y_{predicted}) \quad (4)$$

where:

$Y_{observed}$ = observed value of the dependent variable
$Y_{predicted}$ = predicted value of the dependent variable

The *relative residual* is dimensionless (it has no units) since it is a ratio of two values with the same units (equation 5). The relative residual indicates the relative closeness of the predicted value to the observed value of the dependent variable. It can take both positive and negative values. It is positive when the observed value of the dependent variable is less than the predicted value and negative when the observed value of the dependent variable is greater than the predicted value (in all cases when the observed value of the dependent variable is positive). It is not always the case however that there is complete correspondence between the spatial distribution of the basic residual and the relative residual (the reasons for this and the implications for spatial analysis are explored in more detail by Thomas, 1968). The relative residual may be used in a similar way to the basic residual in spatial analysis.

$$\textit{Relative residual} = (Y_{predicted} - Y_{observed}) / Y_{observed} \quad (5)$$

where:

$Y_{observed}$ = observed value of the dependent variable
$Y_{predicted}$ = predicted value of the dependent variable

The *ratio of estimated to observed values* of the dependent variable (equation 6) is very closely related to the relative residual described above. According to strict definitions, the ratio of estimated to observed values of the dependent variable is not a true residual. True residuals express the magnitude of the difference between estimated and observed values in either absolute or relative terms. When the value of this ratio is less than one the relative residual has a negative value. When the value of this ratio is greater than one the relative residual has a positive value. The ratio of estimated to observed values of the dependent variable may be used in the same way as the relative residual. Since this measure is very closely related to the relative residual only the relative residual is used in this study.

$$\text{Ratio of estimated to observed values} = (Y_{predicted} \,/\, Y_{observed}) \quad (6)$$

The *standardised residual* gives the magnitude of the difference between the estimated and observed value of the dependent variable in terms of the standard error of estimate (equation 7). The overall spatial distribution of the standardised residual is similar to the distribution of the basic residual. Standardised residuals are more amenable to mapping and interpretation however. Their value is always in the range between -3 and +3 regardless of the numerical range of the dependent variable. This allows the residuals to be easily divided into class intervals for mapping. The magnitude of the standardised residual indicates the relative rarity of the difference between predicted and observed values.

$$\text{Standardised residual} = (Y_{observed} - Y_{predicted}) \,/\, s_e \quad (7)$$

where:

$Y_{observed}$	= observed value of the dependent variable
$Y_{predicted}$	= predicted value of the dependent variable
s_e	= standard error term = $(\Sigma(Y_{predicted} - Y_{observed})^2 / (n - k - 1))^{0.5}$
n	= number of observations
k	= number of predictor variables used in the regression equation

After examining the link between various socio-economic and land use characteristics and travel distance, residual analysis is used in this study to identify other characteristics that also might influence travel distance. The philosopher John Stuart Mill identified the 'method of residues' as one of the four basic canons of scientific investigation. His fourth canon states: *"subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents"* (Mill, 1854). This is the basis of residual analysis. It is an iterative process in which a first hypothesis is constructed and tested. The part not explained (the residual) is examined in order to construct a second hypothesis. In this study the first hypothesis concerns the relationship between travel distance, socio-economic and land use characteristics which is tested using multiple regression analysis. The part not explained by the regression equation is assumed to be influenced by other socio-economic and land use characteristics. The socio-economic and land use characteristics of areas where there are significant differences between observed and predicted values of travel distance are then examined in closer detail in order to identify other possible characteristics that might explain some of the differences between predicted and observed values of travel distance. In this study the terms 'hotspots' and 'coldspots' are used to denote areas where the predicted value of travel distance is significantly higher or lower than expected (areas with high or low residuals).

6.2.4 Interviews with Planning and Transport Professionals

In order to identify and explore some of the other land use and socio-economic reasons that might underlie the existence of these 'hotspot' and 'coldspot' wards, discussions were held with local professionals involved in land use and transport planning. Detailed travel patterns and socio-economic characteristics for each of the 'hotspot' and 'coldspot' wards were presented to the interviewees who were then asked to identify land use and socio-economic characteristics that might be responsible for travel distance being significantly above or below the expected value[1].

6.3 The Strengths and Weaknesses of the Approach

The critique of empirical studies revealed some weaknesses (see section 3.3). This section identifies how many of the weaknesses have been overcome in the design and execution of this study. Having done so, the limitations and the overall strengths and weaknesses of the study are assessed.

One of the weaknesses of some studies reviewed in chapter 3 concerns the accuracy of travel distance measurements. However, because this study is comparative, absolute distances are less important than relative distances. The calculation of travel distance has a similar degree of accuracy in each survey area which means that travel distances are comparable within each of the surveys. In the case of the analysis of National Travel Survey data, the distance of each

1. The expected value of travel distance per person determined from the regression equation.

journey was recorded according to 12 distance categories from which travel distance is estimated (see section 5.2.1). In the case of the travel data from Kent and Leicestershire, travel distance was not recorded so two estimates of travel distance were calculated and checked against each other (see section 8.1).

The applicability of average fuel consumption figures to calculate transport energy consumption is identified as a weakness of some of the studies reviewed in chapter 3. Since fuel consumption is not calculated in this study this issue does not arise. It has been established in the previous chapter that fuel consumption per person is anyway very closely correlated with travel distance per person.

The issue of the reliability of data from self-completed questionnaires is also identified as a weakness of some studies since this type of data collection may not provide comprehensive information about all types of journeys, especially short trips. Only the data from Kent is based on self-completed questionnaires however. Interviewers collected the National Travel Survey and Leicestershire data. The comparison of the travel data from Kent and Leicestershire, in which similar journey details were recorded, provides a way of identifying whether under-recording of self-completed questionnaires is likely. For the purposes of this study the under-recording of short journeys is not considered very important anyway since short trips are not likely to substantially contribute total travel distance per person which is the principal measure of travel patterns examined in the study.

Some of the studies reviewed in chapter 3 might be criticised on the issue of sample size, the type of journeys recorded and the time period over which the data is collected. Data for each of the National Travel Surveys were collected continuously over a two or three-year period (in which each person surveyed was questioned about travel over one week) which precludes criticism about the data collection time period. Travel data was collected over a much shorter time period in Kent and Leicestershire (four days in Kent and one day in Leicestershire) but comparison with the National Travel Surveys data provides a way of identifying whether there are major differences in data or results. Since both the national and local travel data examined in this study include all types of journeys, the study avoids criticisms about the exclusion of certain journey purposes.

In common with other cross-sectional empirical studies of land use and transport, this study cannot identify the causality of links between travel patterns, land use and socio-economic characteristics although the research is able to provide detailed analysis beyond the simple correlation analyses presented in many other studies. There is no easy way to identify causality however, even with longitudinal data (which this study does not have). The research has a number of strengths that many studies reviewed in chapter 3 do not share. First, the study covers a wider spectrum of land use characteristics than many other studies. Second, the analysis has a temporal dimension in which changes in the links between land use characteristics and travel is examined. This has not been done in other studies. Third, the research accounts for many of the confounding factors (socio-economic characteristics) that many other studies have omitted or only partially explored. The links between travel distance and a large number of socio-economic characteristics are examined in this study. The use of multiple regression analysis is one way in which links between land use and travel patterns are examined in more detail than with correlation analysis.

Holding variables constant to identify a link between land use characteristics and travel patterns is not easy in empirical research since different areas have unique combinations of land use (and socio-economic) characteristics. This adds complexity to the comparison of travel patterns in different areas. The use of multiple regression analysis helps to disentangle the links between a large number of variables. The results of regression analyses help to identify statistical dependence between variables although they do not identify physical relationships between variables. As with correlation analysis, regression analysis may identify a link between variables but this link may or may not be direct. The overall strengths and weaknesses of the study are summarised in Table 6.4.

TABLE 6.4 THE STRENGTHS AND WEAKNESSES OF THE STUDY

Strengths	*Weaknesses*
• The study identifies evidence for potential links between land use, socio-economic characteristics and travel patterns • It examines the temporal changes in the links between land use, socio-economic characteristics and travel patterns • It presents two levels of analysis (at the individual and the survey area) • The study examines a range of different land uses characteristics • It compares between the results of similar analyses for different sets of data	• The method does not provide a spatial analysis of environmental impacts or exposures • Regression analysis does not identify synergies between the different land uses (but quantitative analysis allows for partial assessment) • The method does not positively identify causality

6.4 SUMMARY

The study is cross-sectional and allows the exploration of interactions between land use, socio-economic characteristics and travel patterns. The study identifies associations between land use, socio-economic characteristics and travel patterns from which other work may be able to establish causal links (the study cannot positively identify causality since it is not longitudinal). The study is able to examine the temporal stability of relationships between land use, socio-economic characteristics and travel patterns by comparing data across a time period of more than a decade (using data from National Travel Surveys of 1978/79, 1985/86, 1989/91 and 1991/93).

The use of local transport data from Kent and Leicestershire provides a means of validating the results from the national travel data and provides a way of examining links between land use characteristics and travel patterns. The exploration of these interactions provides better understanding of the extent to which both socio-economic and land use characteristics might influence travel patterns. The use of both socio-economic and land use characteristics in the study increases the complexity of analysis but improves understanding of the interactions.

It is clear from the review of research concerning land use and travel patterns that most studies concerned with the links between land use planning and travel patterns have excluded the links between socio-economic characteristics on travel patterns. Similarly, many studies concerned with the links between socio-economic characteristics and travel patterns have excluded the links between land use characteristics and travel patterns.

This study considers the links between land use, socio-economic characteristics and travel patterns. The starting point is a set of relationships in which socio-economic and land use characteristics are interlinked with travel patterns. Furthermore, the interactions between socio-economic characteristics, land use characteristics and travel patterns are two-way in which cause and effect are mutable. Some studies have recognised that both land use and socio-economic characteristics (including demographic characteristics) may influence travel patterns but the links between land use, socio-economic characteristics and travel patterns have largely been under-investigated. This study contends that there is an interaction between land use, socio-economic characteristics and travel patterns.

Travel distance is used as the principle measure of travel patterns in this study since it is a reasonable proxy for transport emissions and energy consumption. The relationships between land use characteristics and travel patterns are the main focus of this study, whilst socio-economic variables are used as control variables in order to allow comparison between areas with different socio-economic characteristics. Several sets of data and a number of analytical techniques are used in order to explore the relationships between socio-economic characteristics, land use and travel distance. Two types of data set are examined: data from National Travel Surveys of 1978/79, 1985/86, 1989/91 and 1991/93 and data from two travel surveys carried out in 1995 in Kent and Leicestershire. The Data Archive at the University of Essex provided the National Travel Survey data. Kent County Council and Leicestershire County Council provided the local survey data.

The research employs both a deductive and inductive approach. The analysis of National Travel Survey data is mainly deductive: testing the relationships between travel patterns, socio-economic characteristics and land use characteristics identified in other studies. The analysis of the local travel data is both deductive and inductive. The relationships between travel patterns, socio-economic characteristics and land use characteristics identified in other studies are first tested and the relationships are compared to those found in the analysis of the National Travel Survey data. Secondly, the differences between the predicted and observed values of travel distance are calculated and possible explanations for differences are identified.

Multiple regression analysis techniques are used to examine the relationships between land use, socio-economic characteristics and travel distance. Travel distance is the dependent variable and land use and socio-economic characteristics are the independent variables in regression analysis. Key socio-economic characteristics are identified using stepwise multiple regression. Residual analysis is also used to identify other possible socio-economic and land use characteristics that may influence travel distance. Discussions are held with local professionals involved in land use and transport planning in order to identify and explore some of the other land use and socio-economic reasons that might underlie the existence of these 'hotspot' and 'coldspot' wards.

Data from the National Travel Surveys allow for extensive examination of the relationships between travel distance and socio-economic characteristics since a large amount of socio-economic data was collected in each of these surveys. Only a limited amount of land use data was recorded in these surveys however which do not therefore allow for very detailed analysis of the relationships between travel distance and land use characteristics. The land use characteristics recorded comprise urban population size, local authority population density and proximity to rail and bus services and local population density. It is not possible to supplement the data with additional land use information for each of the areas surveyed for the National Travel Survey since the data sets are recorded in an anonymous format. The local surveys on the other hand contain only a limited amount of socio-economic data but it is possible to establish much more information about land use characteristics for the survey areas through Census data. Thus, the two types of surveys (national and local) are complementary and provide a detailed way of analysing the relationships between travel distance and socio-economic and land use characteristics. The National Travel Survey data are particularly useful for the examination of socio-economic characteristics and also for examining changes in the relationships between travel distance and socio-economic characteristics over time. The two main advantages in examining data from the local surveys are the availability of more extensive land use data and more recent data. Both local travel surveys were carried out in 1995 whereas the most recent data set available from the National Travel Survey is 1991/93. The data allow for analysis of the interaction between socio-economic characteristics, land use and travel distance and also allows for the analysis of these relationships over time.

The weaknesses of other empirical studies that have examined relationships between urban form and travel patterns have been identified in order to establish how they might be overcome in this study. The strengths of the study include a more exhaustive approach to identifying potential links between land use, socio-economic characteristics and travel patterns than in previous studies. It examines the potential links between a large number of socio-economic characteristics and a variety of different land use characteristics. The study examines the changes in these links over time to identify whether there is a temporal dimension to these links. It employs data from both the national and local level and analyses them at the individual level and at the survey area level.

CHAPTER 7: ANALYSIS OF NATIONAL TRAVEL DATA

This chapter explores the variation in travel distance per person and examines the extent to which land use and socio-economic characteristics explain this variation. It then examines how these relationships change over time and identifies a number of key socio-economic predictors of travel distance. Data from four consecutive sets of Great Britain National Travel Surveys (carried out in 1978/79, 1985/86, 1989/91 and 1991/93) are examined (Department of Transport, 1992a and b and Department of Transport, 1995a).

A set of more than 30 socio-economic characteristics are used as explanatory variables for regression analysis. Among these are social, economic and demographic variables such as age, gender, employment status, car and driving licence ownership, household size and composition. According to Ewing (1995), these variables have seldom been considered together in travel research because they have been assumed to measure the same attributes of households (socio-economic group and car ownership for example). In this study all the variables are not so highly correlated that they measure the same attributes. In other words, none of the variables display extremely high multicollinearity (statistical association between variables)[1].

Travel distance per person is the dependent variable used in the regression analysis. Stepwise regression is used to identify the main socio-economic and land use variables which explain the variation in the dependent variable. This method of analysis was chosen since it provides a way of identifying the most important variables that explain the variation in the dependent variable (in other words, unimportant variables are not included in the regression equation) and because it offers a way of reducing potential problems of high multicollinearity between variables (Shaw and Wheeler, 1994 p.257). Other tests were also carried out during the course of regression analyses to avoid problems of multicollinearity.

The links between travel distance, socio-economic and land use characteristics are explored at two levels in this chapter: at the individual level and the survey area level. Similar socio-

1. Some variables are correlated, although never with a correlation coefficient greater than 0.75.

economic and land use characteristics are examined at both levels and similar techniques of analysis are used. However, the measurement of some of these characteristics at the two different levels is different. The socio-economic and land use characteristics examined at the individual level of analysis are all measured using dichotomous (or dummy) variables due to the way in which data were recorded in the National Travel Surveys (see below). Dummy variables are used in preference to variables measured on an interval scale since many relationships between travel distance and socio-economic or land use characteristics is not likely to be linear. For example, age may be linked with the dependent variable, distance per person, but the link is very unlikely to be proportional to age. Similarly, the number of adults or children or cars in a household may influence the travel distance of an individual but there may or may not be a linear relationship (it may be that there is a threshold effect between travel distance and these variables rather than a linear relationship). Dummy variables are better able to explore these links than variables measured on an interval scale. The use of dummy variables in regression analysis is as valid as the use of variables measured on an interval scale (see Hardy, 1993 for example). Where there are *n* categories of a particular variable, *n-1* dummy variables are used. A large number of dummy variables are used for certain categories of variables (such as age and household structure) since the research is designed to be as explorative as possible with such a rich set of socio-economic and travel data.

7.1 NATIONAL TRAVEL SURVEY DATA

The first National Travel Survey was carried out between 1965 and 1966. Subsequent National Travel Surveys were carried out in 1972/73, 1975/76, 1978/79 and 1985/86. From 1988, the National Travel Survey has been carried out on a continuous basis and reported annually.

The type of data recorded in each of the National Travel Surveys has remained quite similar since the original survey of 1965/66. The data are primarily collected to provide national policy-makers with a database of information to investigate policy issues. The data also provide a rich source of travel information for research purposes, and the data from each of the National Travel Surveys from 1978/79 onwards are available to academic researchers through the Data Archive at the University of Essex (with the exception of the most recent three years of data).

The National Travel Survey contains detailed information on personal passenger travel across Great Britain, including data on the purpose, distance, frequency and cost of journeys. It also contains some detailed information about the personal characteristics of the traveller and the traveller's household, including a range of socio-economic data such as age, occupation, car ownership and household composition. The National Travel Survey also contains a more limited set of geographical information about each survey area, including settlement size, population density (of both the local authority and the small area from where the sample was drawn) and the proximity to certain local facilities. However, the precise location of the survey areas is not disclosed, which means that the information is technically non-spatial. As a consequence, it is only possible to examine a limited number of spatial characteristics (only those that relate to the land use characteristics recorded in the survey) and the data is less amenable to residual analysis in a spatial sense than the travel data from the case study areas (Chapter 8).

Each of the survey areas in National Travel Survey are drawn at random from a postcode address file. In the first stage of the sampling process, approximately 240 survey areas are selected each year from a list of almost 8,500 postal sectors in Great Britain, each containing around 2,500 addresses. In the second stage of the process, 21 households are randomly selected from each survey area, providing a sample of around 5,000 households per year. The sampling process has been designed to provide a representative cross-section of geographical areas and households.

7.2 Regression Analysis at the Individual Level

Travel distance per person per week was calculated from National Travel Survey data (described in section 5.2.1) for each of the four surveys. Stepwise multiple regression analysis was then used to identify the key socio-economic and land use characteristics that explain the variation in travel distance per person. Individual, household and land use variables were included in the regression analysis (all the variables are listed in Appendix 2). The regression analyses of data from four National Travel Surveys (1978/79, 1985/86, 1989/91 and 1991/93) produced similar multiple coefficients of explanation (R^2 values of 0.22, 0.24, 0.23 and 0.22 respectively[1]). Thus, only a minor proportion (around one quarter) of the variation in travel distance per person was explained by socio-economic and land use characteristics at the individual level of analysis.

The results of the regression analyses, together with a summary table comparing the results of the regression analyses for each of the four sets of data, are presented in Appendix 3. The summary table (at the end of Appendix 3) indicates the strengths of the partial regression coefficients from multiple regression according to the value of the beta weights ('standardised' partial regression coefficients). The larger the numerical value of the beta weight, either negative or positive, the greater its importance in accounting for the behaviour of the dependent term (Shaw and Wheeler, 1994 p.252). Conclusions from the regression analyses are drawn where the beta weight values show some consistency for each of the four sets of National Travel Survey data. The main results from these regression analyses at the individual level are presented below.

7.2.1 Socio-Economic Characteristics

Analyses of National Travel Survey data at the individual level reveal that there are substantial variations in travel distance according to individual characteristics (see summary table at the end of Appendix 3). These characteristics include gender, age, work status and the possession of a driving licence. Men travel further than women on average. People aged between 30 and 39 travel the most whilst children aged 10 or under travel the least. Persons in full-time work travel most whilst those in retirement travel the least. People with a driving licence travel further than those with only a provisional licence and those without a licence. The extent to which travel distance differs in these categories differs is summarised in Table 7.1.

1. The multiple coefficient of variation values (R^2 values) indicate the percentage of the variation in the dependent variable, total distance travelled per person per week, which can be 'explained' by the independent variables. The R^2 value provides a measure of the goodness of fit of the regression equation (Ebdon, 1985).

TABLE 7.1 INDIVIDUAL CHARACTERISTICS AND TRAVEL DISTANCE

Individual characteristic	*Category in which travel distance is highest*	*Category in which travel distance is lowest*	*Difference in travel distance between highest and lowest categories[1] (km/person/week)*
Gender	Male	Female	27-30
Age	Persons aged between 30 and 39	Children aged under 10 years	12-37
Employment status	Persons in full-time employment	Persons in retirement	92-117
Possession of a driving licence	Persons with a full driving licence	Persons with no driving licence	56-62

Source: Department of Transport (1992a, 1992b and 1995b).

Analyses of National Travel Survey data reveal that there are also links between a number of household characteristics and travel distance (see the summary table at the end of Appendix 3). These characteristics include household socio-economic group, car ownership and household composition. Residents of households in socio-economic group 1 (professional/ managerial) travel further than residents of households in lower socio-economic groups, particularly group 4 (semi-skilled manual professions). People in households with three or more cars travel the most whilst residents of households without a car travel the least. Residents of households containing two adults and no children (and where the head of the household is under 30 years old) travel more than residents in most other categories of household composition. The extent to which travel distance differs in these categories differs is summarised in Table 7.2. Other household characteristics such as the number of children or employed persons in the household and the number of people with driving licences have a smaller, less consistent or unclear effect on travel distance per person.

1. The difference in travel distance between the highest and lowest categories was calculated from the partial regression coefficients presented in Appendix 3.

TABLE 7.2 HOUSEHOLD CHARACTERISTICS AND TRAVEL DISTANCE

Household characteristic	*Category in which travel distance is highest*	*Category in which travel distance is lowest*	*Difference in travel distance between highest and lowest categories[1] (km/person/week)*
Socio-economic group	Households in socio-economic group 1 (professional/ managerial)	Households in socio-economic group 4 (semi-skilled manual)	54-83
Car ownership	Households with three or more cars	Households without a car	112-172
Household composition	Households containing two adults (head of household is under 30) and no children	Most other types of households	27-47

Source: Department of Transport (1992a, 1992b and 1995b).

7.2.2 Land Use Characteristics

Only one land use characteristic, ward population density, emerges as having a consistent and significant effect on travel distance per person. A second land use characteristic, bus frequency, appears to have an influence on travel distance since 1985/86. Residents of low-density wards (with fewer than 10 persons per hectare) travel longer distances than residents of most other wards. Low ward-level density adds between 8 and 25 kilometres to the total distance travelled per person per week (8 kilometres in 1978/79, 24 kilometres in 1985/86, 25 kilometres in 1989/91 and 20 kilometres in 1991/93). Residents of areas with low bus frequencies (with fewer than one bus every hour) travel longer distances. In 1978/79 there was little difference in travel distance between the residents of areas with higher bus frequencies and residents of areas with lower bus frequencies whereas in 1991/93 residents of areas with lower bus frequencies travelled 40 kilometres more than residents of areas with higher bus frequencies. The extent to which travel distance differs in these categories differs is summarised in Table 7.3. Other land use characteristics such as settlement size, the proximity to local facilities (post office, chemist and grocers), the distance to high street shops, the proximity to a bus stop or railway station and local authority population density have a smaller, less consistent or unclear effect on travel distance per person.

1. The difference in travel distance between the highest and lowest categories was calculated from the partial regression coefficients presented in Appendix 3.

TABLE 7.3 LAND USE CHARACTERISTICS AND TRAVEL DISTANCE

Land use characteristic	*Category in which travel distance is highest*	*Category in which travel distance is lowest*	*Difference in travel distance between highest and lowest categories*[1] *(km/person/week)*
Ward-level population density	Less than 10 persons per hectare	Most other densities	8-25
Bus frequency	Fewer than one bus per hour	More than one bus per hour	up to 40

Source: Department of Transport (1992a, 1992b and 1995b).

7.2.3 Summary of Socio-Economic and Land Use Effects on Travel Distance

Including both socio-economic and land use variables in the regression analysis does not greatly increase the power of explanation of the regression equation than when only socio-economic variables are included in the regression analysis, suggesting that there may be interactions between socio-economic and land use characteristics. Consequently the extent to which socio-economic and land use variables explain the variation in travel distance has been calculated as a range (Table 7.4). Socio-economic characteristics explain between 19 and 24 per cent of the variation in travel distance per person whilst land use characteristics only explain up to 3 per cent of the variation in travel distance per person. The results from all four sets of data are quite consistent in this respect. The variance inflation factor[2] (VIF) is shown in the output statistics from the regression analyses as a check for multicollinearity. According to Hair et al (1995 p.152), a usual threshold for identifying high collinearity or multicollinearity between independent variables is a VIF value in excess of 10.0. Of the large number of regression analyses carried out in this study, there is only one case in which any VIF values exceed the value of 10.0 (in the regression analysis of distance per person with land use and socio-economic characteristics at the individual level using the 1978/79 National Travel Survey data – see Appendix 3).

1. The difference in travel distance between the highest and lowest categories was calculated from the partial regression coefficients presented in Appendix 3.

2. The variance inflation factor is equal to $1/R_i^2$, where R_i^2 is the coefficient of determination for the prediction of variable by the other predictor variables (see Hair et al, 1995 p.152).

TABLE 7.4 REGRESSION ANALYSIS RESULTS AT THE INDIVIDUAL LEVEL WHERE DISTANCE PER PERSON IS THE DEPENDENT VARIABLE

		R^2 values		
	1978/79	*1985/86*	*1989/91*	*1991/93*
All land use variables	0.02	0.02	0.03	0.02
All socio-economic variables	0.22	0.24	0.22	0.21
All land use and socio-economic variables[1]	0.22	0.24	0.23	0.22
Range of effect of land use variables[2]	0.00-0.02	0.00-0.02	0.01-0.03	0.01-0.02
Range of effect of socio-economic variables[3]	0.20-0.22	0.22-0.24	0.19-0.22	0.20-0.21
Sample size (number of individuals)	21,888	24,357	25,104	24,067

Source: Department of Transport (1992a, 1992b and 1995b).

7.3 REGRESSION ANALYSIS AT THE SURVEY AREA LEVEL

The calculations of distance per person at the individual level of analysis (reported in the previous section) were aggregated for each of the survey areas in the four National Travel Surveys (712, 720, 719 and 738 areas were surveyed in 1978/79, 1985/86, 1989/91 and 1991/93 respectively). Stepwise multiple regression analysis was again used to identify the key socio-economic and land use characteristics that explain the variation in travel distance per person. Both socio-economic and land use variables were included in the regression analysis (all the variables are listed in Appendix 4). The results of the regression analyses at the survey area level, as with the results of the analyses at the individual level (presented in section 7.2), produced fairly similar multiple coefficients of explanation for each of the 1978/79, 1985/86, 1989/91 and 1991/93 National Travel Surveys (R^2 values of 0.44, 0.55, 0.58 and 0.56 respectively[4]). A larger proportion of the variation in travel distance per person was explained by socio-economic and land use characteristics at the survey area level of analysis than at the individual level of analysis. Again, more of the variation in travel distance

1. All regression equations containing land use and socio-economic variables are presented in Appendix 3.

2. The R^2 value for the regression of all land use variables gives the upper value for the range of effect. The lowervalue for the range of effect is calculated by subtracting the R^2 value for the regression of all socio-economic and land use variables from the R^2 value for the regression of all socio-economic variables.

3. The R^2 value for the regression of all socio-economic variables gives the upper value for the range of effect. The lower value for the range of effect is calculated by subtracting the R^2 value for the regression of all socio-economic and land use variables from the R^2 value for the regression of all land use variables.

4. The multiple coefficient of variation values (R^2 values) indicate the percentage of the variation in the dependent variable, total distance travelled per person per week, which can be 'explained' by the independent variables. The R^2 value provides a measure of the goodness of fit of the regression equation (Ebdon, 1985). Other ways of indicating goodness of fit such as the mean absolute deviation and the scatter of predicted values (from the regression equation) and actual values are also presented in Appendix 5.

per person was explained by socio-economic than land use characteristics. The variables explained more of the variation in the independent variable in the three newer sets of data (1985/86, 1989/91 and 1991/93) than the data for the 1978/79 survey.

The results of the regression analyses, together with a summary table comparing the results of the regression analyses for each of the four sets of data, are presented in Appendix 5. The summary table (towards the end of Appendix 5) indicates the strengths of the partial regression coefficients from multiple regression according to the value of the beta weights ('standardised' partial regression coefficients). Conclusions from the regression analyses are drawn where the beta weight values show some consistency for each of the four sets of National Travel Survey data. Certain variables were omitted from the regression analysis where high multicollinearity was detected[1]. The main results from these regression analyses are presented below.

7.3.1 Socio-Economic Characteristics

Average travel distance is higher in areas where there is a high proportion of driving licences per household. Travel distance is also higher in areas where there is a high ratio of cars per person. Average travel distances are high in areas where there are large proportions of households in socio-economic group 1 (professional/managerial socio-economic group). Conversely, average travel distance per person is lowest in areas where there are large numbers of households in socio-economic groups 3, 4 and 5 (skilled, semi-skilled and unskilled manual employment respectively). Household characteristics such as the age profile, level of employment and household structure have a less consistent influence on travel distance.

From the large number of socio-economic variables examined above, a smaller set of key socio-economic characteristics were then identified in order to:

(i) provide a smaller number of proxy socio-economic variables that explain most of the variation in travel distance per person

1. All variables with high VIF values (exceeding 10.0) were excluded (see section 7.2.3).

(ii) test the relationships between socio-economic variables and travel distance per person in the case study areas (since only a limited amount of socio-economic data was collected in the Kent and Leicester travel surveys)

Key socio-economic variables were identified by examining the importance of the socio-economic variables in the regression equations at the survey area level (Appendix 5). Seven key variables were identified that are significant in all four regression analyses at the survey area level of analysis. Together these seven key socio-economic characteristics explain almost as much of the variation in travel distance per person as all the socio-economic variables included in the regression analysis together. These seven key variables are:

(i) the average number of cars per person (CARSPP)
(ii) the average proportion of employed persons in the area (PWORKERS)[1]
(iii) the percentage of households in which the head of household is in managerial or professional employment (PSEG1)
(iv) the percentage of households in which the head of household is in clerical non-manual employment (PSEG2)
(v) the percentage of households in which the head of household is in skilled manual employment (PSEG3)
(vi) the percentage of households in which the head of household is in semi-skilled manual employment (PSEG4)
(vii) the percentage of households in which the head of household is in unskilled manual employment (PSEG5)

The average number of cars per person is consistently the most significant variable in explaining the variation in average travel distance per person. Average travel distance increases as the average number of cars per person in an area increases. The socio-economic profile of the area, described by the five variables identifying the proportion of households in socio-economic groups 1, 2, 3, 4 and 5 (PSEG1, PSEG2, PSEG3, PSEG4 and PSEG5), has a strong influence on average travel distance. As the proportion of households in socio-economic group 1 increases, average travel distance per person increases. As the proportions of households in socio-economic groups 3, 4 and 5 increase, average travel distance per person decreases. The proportion of people in paid employment (expressed as a percentage of

1. A variable describing the proportion of employed persons in the area features in all regression equations although it is not always the variable PWORKERS: the variables PPTWORKRS and PFTWORKRS sometimes feature as well or instead.

the total population in employment) is also a significant variable in explaining the variation in average travel distance per person for all four sets of data. Average travel distance increases as the proportion of people in work increases. The seven key variables explain more of the variation in travel distance per person in the three most recent sets of data (1985/86, 1989/91 and 1991/93).

7.3.2 Land Use Characteristics

Regression analysis shows that land use characteristics, such as ward-level population density, the proximity to local facilities, bus frequency and settlement size are linked to travel distance at the survey area level of analysis. The results suggest that average travel distance is higher by up to 14 kilometres per person in areas with low ward-level population density (less than 10 persons per hectare), with the exception of evidence from the data for 1978/79, which indicates a trend that may have emerged since 1978/79. Average travel distance is consistently lower in London by up to 43 kilometres per person per week. The effect of other sizes of settlement on average travel distance is less clear. Other land use characteristics examined (including local authority population density and the proximity to high street shops, bus stop or railway station) do not have a clear, consistent or significant link with travel distance per person.

7.3.3 Summary of Socio-Economic and Land Use Effects on Travel Distance

Multiple regression analysis indicates that socio-economic variables alone account for approximately half of the variation in travel distance per person (less in 1978/79). Land use variables alone explain around a quarter (between 21 and 27 per cent) of the variation in travel distance. However, the overall power of explanation obtained from regression analysis including both socio-economic and land use variables is not equal to the sum of R^2 values for the two regression equations where socio-economic variables and land use variables were included separately. Indeed, the coefficient of explanation (R^2) for the variation in average travel distance per person only increased by a few percentage points when both the socio-economic and land use variables were included in the regression analysis together, compared to the regression analysis including socio-economic variables alone.

The extent to which socio-economic and land use variables explain the variation in travel distance has therefore been calculated as a range (Table 7.5). Socio-economic characteristics explain between 23 and 55 per cent of the variation in travel distance per person whilst land use characteristics explain between 1 and 27 per cent of the variation in travel distance per person at the survey area level of analysis. The results from all four sets of data are quite consistent although less of the variation in average travel distance per person is explained in 1978/79 than in the analysis of the more recent National Travel Survey data. Socio-economic variables consistently explain more of the variation in travel distance per person than land use variables. The seven key variables in regression analyses for each of the 1978/79, 1985/86, 1989/91 and 1991/93 National Travel Survey data produced similar multiple coefficients of explanation (R^2) values[1].

TABLE 7.5 REGRESSION ANALYSIS RESULTS AT THE SURVEY AREA LEVEL WHERE DISTANCE PER PERSON IS THE DEPENDENT VARIABLE

	R^2 values			
	1978/79	*1985/86*	*1989/91*	*1991/93*
All land use variables	0.21	0.25	0.27	0.25
All socio-economic variables	0.43	0.52	0.55	0.51
All land use and socio-economic variables[2]	0.44	0.55	0.58	0.56
Range of effect of land use variables[3]	0.01-0.21	0.03-0.25	0.03-0.27	0.05-0.25
Range of effect of socio-economic variables[4]	0.23-0.43	0.30-0.52	0.31-0.55	0.31-0.51
Seven 'key' socio-economic variables[5]	0.36	0.49	0.47	0.45
Sample size (number of survey areas)	712	720	719	738

Source: Department of Transport (1992a, 1992b and 1995b).

1. An explanation of the multiple coefficient of variation values (R^2 values) can be found in Section 6.2.2
2. All regression equations containing land use and socio-economic variables are presented in Appendix 5.
3. The R^2 value for the regression of all land use variables gives the upper value for the range of effect. The lowervalue for the range of effect is calculated by subtracting the R^2 value for the regression of all socio-economic and land use variables from the R^2 value for the regression of all socio-economic variables.
4. The R^2 value for the regression of all socio-economic variables gives the upper value for the range of effect. The lower value for the range of effect is calculated by subtracting the R^2 value for the regression of all socio-economic and land use variables from the R^2 value for the regression of all land use variables.
5. All regression equations containing the seven 'key' socio-economic variables are presented in Appendix 5.

7.3.4 The Effects of Land Use on Car Ownership

Since car ownership is consistently the most significant socio-economic variable in explaining the variation in travel distance per person (refer to the regression equations in Appendix 5), the interaction between car ownership, other socio-economic characteristics and land use is now examined. In particular the section explores the extent to which car ownership might be influenced by land use characteristics.

Household car ownership is likely to be influenced by social and economic characteristics such as household size, age structure, income and employment type. It is also likely to be determined by land use characteristics such as the proximity to services and facilities (which influence the need for motorised journeys), the cost and/or availability of car parking and the availability and attractiveness of alternative modes (such as walking, cycling and public transport modes).

The link between car ownership, land use and socio-economic characteristics is probably not a simple cause and effect relationship (land use characteristics influencing car ownership for example). It is more likely to be a more complex relationship in which land use features influence car ownership and vice versa. Higher densities for example are associated with less car parking space which may affect the levels of car ownership within an area. Car ownership on the other hand may encourage people to seek residential locations that can accommodate the car (usually lower density developments). Similarly, it also may be that the relationship between socio-economic variables and car ownership is not a simple cause and effect relationship but a more complex relationship. Income levels, employment type and age structure may affect car ownership. Car ownership on the other hand may influence the ability to obtain work and therefore income. Further regression analyses of the National Travel Survey data were carried out to explore some of these interactions.

Where car ownership is the dependent variable in regression analysis and a range of socio-economic and land use variables are the independent variables (some of the same variables used in the regression analyses of average distance per person at the survey area level of analysis reported earlier), between 45 and 82 per cent of the variation in car ownership is explained by socio-economic characteristics (Table 7.6). The most important socio-economic influences on car ownership are the age profile of the area, the proportion of households with a high number of driving licences and household socio-economic status. Car ownership is high in areas where there is a high proportion of persons aged between 40 and 59. Areas with a high proportion of households with three driving licences or more have high car ownership. The ratio of cars per person is high in areas with a high proportion of households in socio-economic group 1 (and low in areas with more households in socio-economic groups 4 and 5).

TABLE 7.6 REGRESSION ANALYSIS RESULTS AT THE SURVEY AREA LEVEL WHERE THE RATIO OF CARS PER PERSON IS THE DEPENDENT VARIABLE

	R^2 values			
	1978/79	*1985/86*	*1989/91*	*1991/93*
All land use variables	0.32	0.37	0.30	0.29
All socio-economic variables	0.77	0.80	0.77	0.77
All land use and socio-economic variables[1]	0.79	0.82	0.80	0.80
Range of effect of land use variables[2]	0.02-0.32	0.02-0.37	0.03-0.30	0.03-0.29
Range of effect of socio-economic variables[3]	0.45-0.79	0.45-0.82	0.50-0.77	0.51-0.77
Sample size (number of survey areas)	712	720	719	738

Source: Department of Transport (1992a, 1992b and 1995b).

Between 2 and 37 per cent of the variation in car ownership is explained by land use characteristics (Table 7.6). The most important land use influences on household car ownership are the proximity to a railway station and the frequency of the local bus service. Car ownership is low in areas within a 6-minute walk from a railway station and high in areas without a frequent bus service (less than 2 buses per hour). The results from all four sets of data are quite consistent in terms of these observations. Other land use characteristics examined (including population density, settlement size and the proximity to high street shops or a bus stop) do not have a clear, consistent or significant link with car ownership.

The results of the regression analyses of car ownership, socio-economic and land use variables, together with a summary table comparing the results of the regression analyses for

1. All regression equations containing land use and socio-economic variables are presented in Appendix 5.
2. The R^2 value for the regression of all land use variables gives the upper value for the range of effect. The lowervalue for the range of effect is calculated by subtracting the R^2 value for the regression of all socio-economic and land use variables from the R^2 value for the regression of all socio-economic variables.
3. The R^2 value for the regression of all socio-economic variables gives the upper value for the range of effect. The lower value for the range of effect is calculated by subtracting the R^2 value for the regression of all socio-economic and land use variables from the R^2 value for the regression of all land use variables.

each of the four sets of data from 1978/79, 1985/86, 1989/91 and 1991/93, are presented in Appendix 5. The summary table (towards the end of Appendix 5) indicates the strengths of the partial regression coefficients from multiple regression according to the value of the beta weights[1]. Conclusions from the regression analyses are drawn where the beta weight values show some consistency for each of the four sets of National Travel Survey data.

7.4 SUMMARY

This chapter has studied the variation in travel distance per person and examined the extent to which land use and socio-economic characteristics explain this variation using data from National Travel Surveys. It has examined the stability of these relationships over time by carrying out regression analysis using four consecutive sets of National Travel Survey data (carried out in 1978/79, 1985/86, 1989/91 and 1991/93).

A set of more than 30 socio-economic characteristics were selected as explanatory variables for regression analysis. Among these were social, economic and demographic variables including age, gender, employment status, car and driving licence ownership, household size and composition. These variables have seldom been considered together in travel research because they have been assumed to measure the same attributes of households (socio-economic group and car ownership for example). In this study all the variables presented in the results of the regression analyses were not so highly correlated that they measure the same attributes. Checks were made in the course of the regression analyses for high multicollinearity. The dependent variable used in the regression analysis was travel distance per person. Stepwise regression was used to identify socio-economic and land use variables which explain some of the differences in travel distance per person.

The examination of National Travel Survey data at the individual level using regression analysis reveals that there are a number of socio-economic characteristics that are linked with travel distance. These include gender, age, individual employment status, the possession of a driving licence, household employment, household composition, household socio-economic status and household car ownership. Men travel further than women. People aged between 30 and 39 travel more than most other age groups. Holders of a driving licence travel further than

1. Refer to section 7.2 for a discussion of beta weights.

people with only a provisional licence and people without a licence. People in full-time work travel further than people in part-time work and those not in work. Residents of households in higher socio-economic groups (particularly households in socio-economic group 1 – where the head of household has a managerial or professional job) travel further than residents of households in lower socio-economic groups (particularly households in socio-economic group 4 – where the head of household has a semi-skilled job). Residents of households containing two adults and no children (where the head of the household is under 30 years old) travel more than other types of households. People in households owning two or more cars travel further than residents of households owning fewer than two cars.

Regression analysis at the individual level reveals that there are also land use characteristics that are linked with travel distance. These include ward population density and possibly the frequency of the bus service. The residents of wards where density is less than 10 persons per hectare travel further on average than residents of higher-density wards. Residents of areas with higher bus frequencies (more than one bus every hour) now appear to travel shorter distances than residents of areas that are less well served by bus.

Socio-economic variables explain between 19 and 24 per cent of the variation in distance travelled per person at the individual level of analysis, whereas land use variables explain consistently less of the variation – up to only three per cent of the variation in average distance travelled per person. Socio-economic and land use characteristics together explain less than one quarter of the variation in travel distance per person at the individual level of analysis.

The examination of National Travel Survey data at the survey area level reveals that a number of socio-economic characteristics are linked to the variation in travel distance per person. These include the number of driving licence per households, household socio-economic status and car ownership. Average travel distance is lowest in areas where a high proportion of households have no driving licence. Travel distance is high in areas where there is a large proportion of households in socio-economic group 1. Conversely, average travel distance is lower in areas where there is a high proportion of households in socio-economic groups 3, 4 and 5. Average travel distance increases as the ratio of cars per person increases.

Regression analysis at the survey area level of analysis reveals that several land use characteristics are linked with travel distance. These include the proximity to local facilities, the frequency of the local bus service, settlement size and ward population density. Travel distance is shorter in areas close to local facilities. Travel distance is higher in areas where the local bus frequency is less than 2 per hour. In terms of settlement size, travel distance is consistently lower in London and in other large urban areas containing more than 250,000 residents. Travel distance has been higher in areas with a population density lower than 10 persons per hectare since 1985/86.

Socio-economic variables explain between 23 and 55 per cent of the variation in distance travelled per person at the survey area level of analysis, whereas land use variables explain consistently less of the variation – up to 27 per cent of the variation in average distance travelled per person across different types of area. Much of the variation in average travel distance per person can be explained by seven 'key' socio-economic variables. These variables comprise:

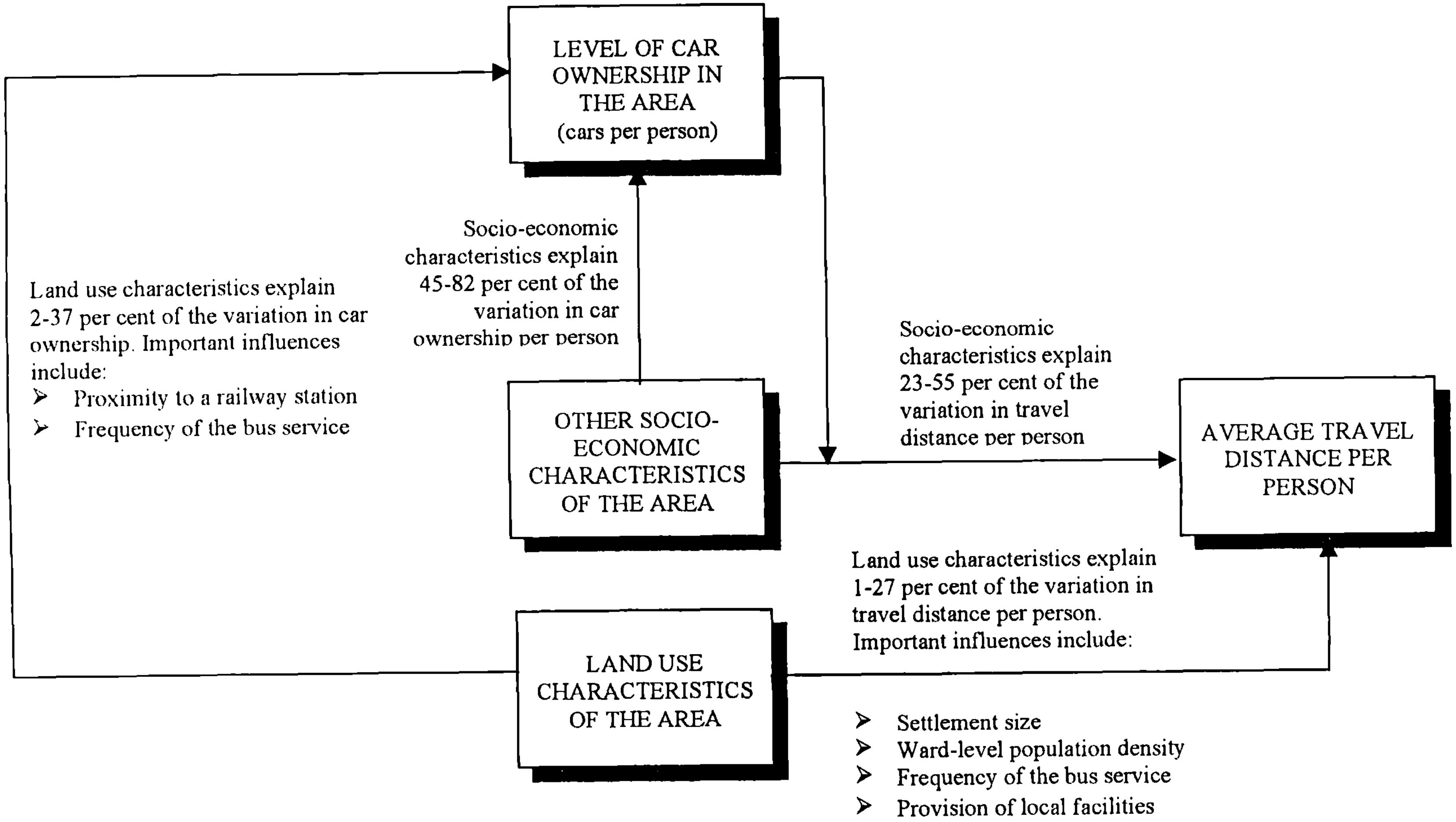
(i) the average number of cars per person
(ii) the proportion of households in socio-economic group 1 (professional and management)
(iii) the proportion of households in socio-economic group 2 (intermediate and clerical)
(iv) the proportion of households in socio-economic group 3 (skilled non-manual)
(v) the proportion of households in socio-economic group 4 (semi-skilled manual)
(vi) the proportion of households in socio-economic group 5 (unskilled manual)
(vii) the proportion of persons in paid employment

The results of the regression analyses suggest that many of the links between land use, socio-economic characteristics and travel patterns have remained quite stable between 1978/79 and 1991/93. There are a few exceptions however. At the individual level of analysis, the link between travel distance and the local bus frequency has changed over time. Local bus frequency had no noticeable association with travel distance in 1978/79. Since 1985/86 however, areas served by more than one bus every hour appear to be associated with shorter travel distances.

More of the variation of travel distance is explained at the survey area level of analysis than at the individual level of analysis, which may be related to the number of data points and the fact that data at the survey area level is aggregated.

Since car ownership is consistently the most significant socio-economic variable in explaining the variation in travel distance per person, the interactions between car ownership, other socio-economic characteristics and land use were examined. Between 45 and 82 per cent of the variation in car ownership is explained by socio-economic characteristics. The most important socio-economic effects on car ownership are the age profile of the area, the proportion of households with a high number of driving licences, household socio-economic status and household structure. The most important land use effects on household car ownership are the proximity to a railway station and the frequency of the bus service. Land use characteristics explain between 2 and 37 per cent of the variation in car ownership in an area. The results from all four sets of data are quite consistent. The interactions identified from the analysis of National Travel Survey data at the survey area level are summarised in Figure 7.1.

FIGURE 7.1 RELATIONSHIPS BETWEEN TRAVEL PATTERNS, LAND USE AND SOCIO-ECONOMIC CHARACTERISTICS



Sources: Tables 7.5 and 7.6 and regression equations in Appendix 5.

CHAPTER 8: ANALYSIS OF LOCAL TRAVEL DATA FROM KENT AND LEICESTERSHIRE

This chapter presents the analysis of travel data from Kent and Leicestershire, the two case study areas. Similar regression analyses are carried out in this chapter as were carried out in the previous chapter with data from the National Travel Surveys. The purpose of these analyses is firstly to test whether the results from the National Travel Survey data are similar to those from local surveys in the case study areas and secondly to examine the effect of other land use features (such as the mixing of land uses and the proximity to the transport network) on travel distance per person. The chapter investigates the links between selected socio-economic characteristics (the seven 'key' variables identified in the previous chapter), a number of land use variables (different to the set of land use characteristics examined in the previous chapter) and travel distance per person.

8.1 THE CALCULATION OF TRAVEL DISTANCE

Before analysis it was necessary to calculate travel distance for each of the journeys recorded in the two local travel surveys since journey distance was not recorded. Two methods were used to calculate travel distance. The first method, termed *the 'straight-line' method*, was used to calculate the crow-fly distance between each journey origin and destination. Since the origin and destination postcodes were recorded in the survey it was possible to convert these into Ordnance Survey Grid References using the Central Postcode Directory. It was then possible to calculate a straight-line distance between the origin and destination for each journey using the grid references. The second method for calculating travel distance, termed *the 'journey-speed' method*, was used to calculate travel distance from information about the mode and travel time of each journey. Tabulations from the 1991/93 National Travel Survey were used to identify the median speeds for each mode (Table 8.1). Typical speeds were identified from these in order to estimate journey distance. The typical speed of most modes shows little variation according to the time of day with the exception of journeys by car which are generally faster in the early morning (midnight to 8am). Analysis of the 1991/93 National

Travel data revealed surprisingly little evidence of lower journey speeds by car during the morning and evening traffic peaks.

TABLE 8.1 JOURNEY SPEED BY MODE, 1991/93

Mode	*Median speed (mph)*	*Typical speed (mph / kmh)*
Walk	0-5	3 / 5
Cycle	5-10	7 / 11
Car (midnight to 8am)	20-25	22 / 35
Car (8am to midnight)	15-20	17 / 27
Van/lorry	15-20	17 / 27
Train	20-30	25 / 40
Underground	15-20	17 / 27
Motorcycle	15-20	17 / 27
Bus	10-15	12 / 19
Express coach	20-25	22 / 35
Taxi/minicab	10-15	12 / 19

Source: Department of Transport (1995b).

Travel distance for each journey was estimated using both 'straight-line' and 'journey-speed' methods described above for the two local travel surveys: the two methods provide a means of checking against each other. Where postcodes were not recorded for journeys, distance was calculated using information about journey time and mode. Conversely, where journey time and mode were not recorded, distance was estimated from the origin and destination postcodes. Where insufficient data were recorded to calculate distance by either of these two methods, journey distance was assumed to be 10 kilometres: the average journey distance in 1993/95 (Department of Transport, 1996b). Where the mode of transport was unspecified, the journey was assumed to be by car. The accuracy of the estimates of journey distance calculated from postcode data is considered in Appendix 6 which shows that the maximum margin of error of journey distance is around 400 metres. The extent to which the estimates of journey distance are comparable is also discussed in Appendix 6 where it is demonstrated that there is close correspondence between the two estimates of travel distance. 'Straight-line' distance is around 10 per cent lower than 'journey-speed' distance.

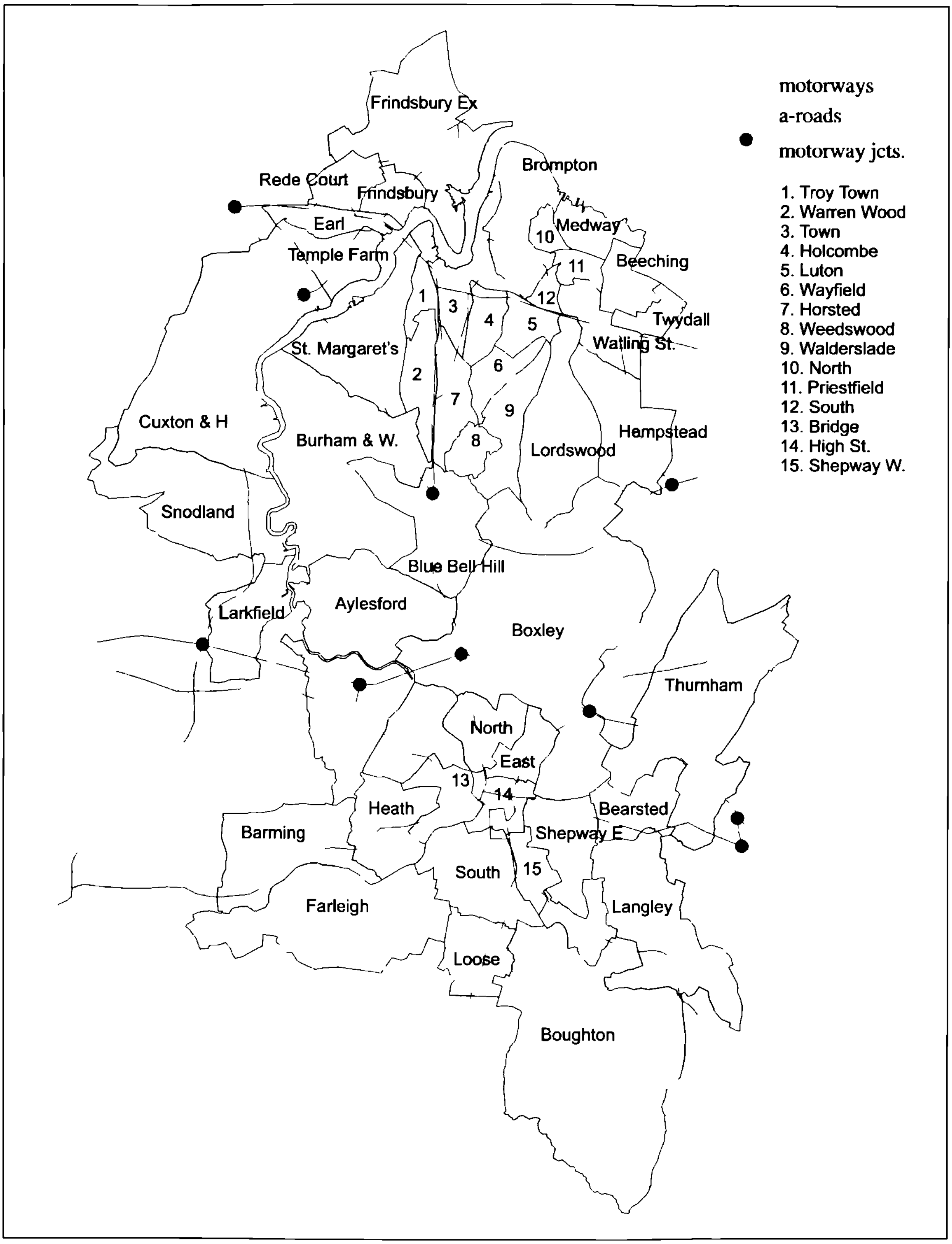
8.2 THE CASE STUDY AREAS

Two case study areas are examined in this chapter – the area around Maidstone and the Medway Towns and around the city of Leicester. The main socio-economic and transport characteristics of these two areas are described in turn below.

8.2.1 Maidstone and the Medway Towns, Kent

The study area is in the north of Kent and covers an area of approximately 22,830 hectares (Figure 8.1). The study area covers Maidstone, the Medway Towns (Chatham, Gillingham and Rochester) and the surrounding area. It comprises 48 wards in four adjoining districts (9 wards in Gillingham, 17 wards in Maidstone, 17 wards in Rochester upon Medway and 5 wards in Tonbridge and Malling). The names of all wards included in this study are set out in Appendix 7. The population of the survey area was 307,045 in 1991 (Office for Population Censuses and Surveys, 1995). The area has a relatively high population density of 13 persons per hectare (more than four times the average population density for England and Wales), ranging from 1 to 106 persons per hectare across the 48 wards. Employment in the area is almost exactly equal to the number of economically active residents, implying that there is a balance between jobs and workers. The study area is mainly urban and covers a number of large industrial towns – Maidstone, Chatham, Strood, Rochester and Gillingham. There are two motorways within the study area: the M2 and the M20 which both run in an east-west direction. The M2 links London (via the A2) with Dover and the M20 links London with Folkestone, running more or less parallel and to the south of the M2. The main railway stations in the area are Chatham and Gillingham and are on the line connecting the ports of Margate, Ramsgate and Dover with London. There are also several smaller railway stations including three stations serving Maidstone (Maidstone Barracks, Maidstone East and Maidstone West). Population and employment are both concentrated in the wards around Maidstone, Chatham, Strood, Rochester and Gilllingham.

FIGURE 8.1 THE LOCATION OF THE KENT SURVEY AREA



Source: Digitised boundaries for Kent [data file]. UKBORDERS, University of Edinburgh.

The travel data for the Medway Towns area comes from a postal household travel survey questionnaire conducted by the Highways and Transportation Department of Kent County Council in June 1995. The travel survey collected data for over 13,000 persons (representing over 6,000 households). Details of all journeys during the course of one day (Tuesday 27 June 1995) were recorded. This included all journey purposes and all travel modes. More than 42,000 journeys were recorded in total. Data from more than 60 wards were recorded. For the purposes of this study, only the wards where more than 10 households had been surveyed were included in the analysis, giving a total of 12,743 persons in 5,757 households across 48 wards.

Various socio-economic indicators of the survey area are summarised in Table 8.2. The average household size in the study area is slightly higher than the average for England and Wales. The proportion of households in each of the five main socio-economic groups is similar to the average for England and Wales. Car ownership is slightly higher than average in the survey area, so too is the proportion of the population in employment.

TABLE 8.2 SOCIO-ECONOMIC AND DEMOGRAPHIC PROFILE OF KENT

	48 wards, Kent	*England & Wales*
Population density (persons/hectare)	13.45	3.12
Household size (persons/household)	2.60	2.51
Cars per person	0.42	0.39
proportion of households in socio-economic group 1	4%	5%
proportion of households in socio-economic group 2	25%	27%
proportion of households in socio-economic group 3	47%	43%
proportion of households in socio-economic group 4	14%	15%
proportion of households in socio-economic group 5	6%	6%
proportion of population in employment	47%	44%

Source: Office for Population Censuses and Surveys (1995).

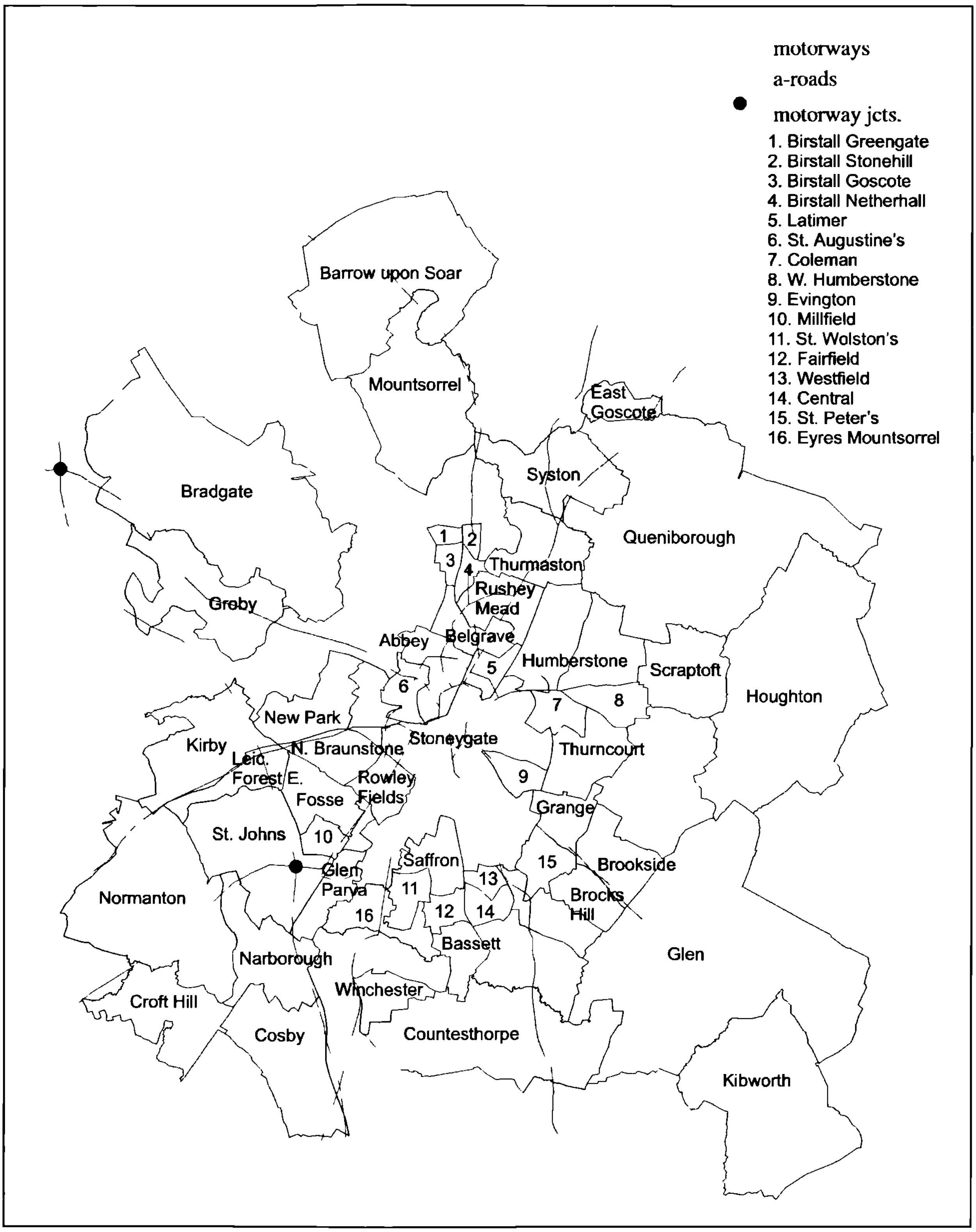
8.2.2 The City of Leicester and the Surrounding Area

The study area is in the middle of the county of Leicestershire and covers an area of approximately 35,350 hectares (Figure 8.2). The population of the survey area was 340,824 in 1991 (Office for Population Censuses and Surveys, 1995). The study area covers 56 wards in six adjoining districts (13 wards in Blaby, 11 wards in Charnwood, 5 wards in Harborough, one ward in Hinckley and Bosworth, 17 in Leicester and 9 wards in Oadby and Wigston). The names of all wards included in this study are set out in Appendix 8. The area has a relatively high population density of 10 persons per hectare, ranging from 1 to 71 persons per hectare across the 56 wards (the average population density of England and Wales is less than 4 persons per hectare).

There are two motorways within the study area: the M1 and the M69. The M1 runs in a north-south direction to the west of the city of Leicester. The M69 joins the M1 in the south-east part of the study area and runs in a south-west direction towards Coventry. The main railway station in the area is in Leicester which has regular rail services in the directions towards London, Birmingham, Derby, Sheffield and Peterborough. There are also several smaller railway stations: Syston, Sileby and Barrow Upon Soar in the north of the area and South Wigston and Narborough in the south-west of the area. Population and employment are both concentrated in the wards around the centre of Leicester. There are approximately 45 per cent more jobs than economically active residents in the City of Leicester. However there is a close match in the total number of jobs and economically active residents in Leicester and the surrounding five districts of Blaby, Charnwood, Harborough, Hinckley and Bosworth and Oadby and Wigston, implying that there is a balance between jobs and workers in Leicester and its nearest surrounding districts.

The travel data for the Leicester area comes from household travel surveys carried out by MVA Consultants in 1995 for the Department of Planning and Transportation, Leicestershire County Council. Over 2,000 persons were included in the household travel survey (929 households). Details of all journeys over the course of four days were recorded in the survey. This included all journey purposes and all travel modes. More than 18,000 journeys were recorded in total. Data from more than 80 wards were recorded in the survey. For the purposes of this study, only wards where more than 10 households had been surveyed were included in the analysis, giving a total of 1,486 persons in 789 households across 56 wards.

FIGURE 8.2 THE LOCATION OF THE LEICESTERSHIRE SURVEY AREA



Source: Digitised boundaries for Leicestershire [data file]. UKBORDERS, University of Edinburgh.

Various socio-economic indicators of the survey area are summarised in Table 8.3. The average population density of the area is more than twice the average for England and Wales. The average household size is slightly higher in the study area than the average for England and Wales. The proportion of households in each of the five main socio-economic groups is generally similar to the average for England and Wales although the proportion of households in socio-economic group 2 (intermediate and clerical professions) is a little lower than average and the proportion of households in socio-economic group 5 (unskilled manual) is slightly higher than average. Car ownership and the proportion of the population in employment are very close to the national average.

TABLE 8.3 SOCIO-ECONOMIC AND DEMOGRAPHIC PROFILE OF LEICESTERSHIRE

	56 wards, Leicestershire	*England & Wales*
Population density (persons/hectare)	9.64	3.12
Household size (persons/household)	2.62	2.51
Cars per person	0.38	0.39
proportion of households in socio-economic group 1	4%	5%
proportion of households in socio-economic group 2	23%	27%
proportion of households in socio-economic group 3	45%	43%
proportion of households in socio-economic group 4	19%	15%
proportion of households in socio-economic group 5	5%	6%
proportion of population in employment	45%	44%

Source: Office for Population Censuses and Surveys (1995).

Thus, the two case study areas are broadly similar in terms of population density, household size, socio-economic composition and level of employment. Car ownership is slightly higher than the national average in Kent whilst car ownership in Leicestershire is close to the average for England and Wales as a whole.

8.3 TRAVEL PATTERNS IN KENT AND LEICESTERSHIRE

Table 8.4 sets out some of the overall travel statistics for the two case study areas. Travel distance per person is expressed within a range since two methods for estimating travel distance have been used (the 'straight-line' method and the 'journey-speed' method[1]). Travel distance per person has been aggregated to give weekly travel figures although it is recognised that the aggregations are not precise (since weekday travel is different to weekend travel for example) and not directly comparable (because the two travel surveys were recorded differently and covered different time periods). The Kent survey was carried out using postal questionnaires which were completed by householders and collected travel data for just one weekday. The Leicestershire survey collected travel data over a four-day period (including a weekend) and was carried out by interviewers. The Kent survey includes travel data for more than 12,000 individuals while the Leicestershire survey includes travel information about relatively fewer individuals (approximately 1,500 persons) but over a longer timescale.

TABLE 8.4 TRAVEL DISTANCE PER PERSON PER WEEK BY JOURNEY PURPOSE

	Distance per person per week (km):[2]							*Journeys per person per week*
	All Purposes	*Education*	*Escorting*	*Shopping*	*Social/ Recreation*	*Work*	*Unspecified*[3]	
Kent	173-190	7-10	4-5	14-24	20-23	62-64	61	20.5
Leicestershire	131-152	5	8-10	17-22	22-23	23-24	57-68	14.6
GB (1994/96)	199	5	15	24	95	61	0	20.3

Sources: Survey data from Kent and Leicestershire and Department of the Environment, Transport and the Regions (1997e).

Despite the differences between the surveys it is still possible to make some general observations about travel patterns in the two case study areas. Similar distances are travelled per person per week for most journey purposes in Kent and Leicestershire. Average travel distance in the Kent case study area is between 173 kilometres and 190 kilometres per person per week which is close to the national average of 199 kilometres per person per week reported in the 1994/96 National Travel Survey (Department of the Environment, Transport and the Regions, 1997e). In the Leicestershire study area, average travel distance is lower than the national average (between 131 kilometres and 152 kilometres per person per week). Three

1. The two methods for calculating travel distance are described in Section 8.1.
2. A range of distance per person for each journey purpose is presented, since two methods for estimating travel distancehave been used (the 'straight-line' method and the 'journey-speed' method).
3. The purpose of some journeys recorded in the Kent and Leicestershire travel data were unspecified and a journey purpose could not therefore be allocated.

journey purposes (work, shopping and social/recreation) account for a large proportion of the total distance travelled in both case study areas. One of the reasons why a greater proportion of the total travel distance is work-related in Kent than in Leicestershire is perhaps because the Kent data relates to weekday travel whereas the Leicestershire data also includes weekend travel. Social and recreation travel distance in both case study areas is much lower than the average for Great Britain. This may be due to the shorter survey period for collection of the travel data in Kent and Leicestershire which may not pick up so much long-distance travel, especially where it involves several days away from home.

8.4 REGRESSION ANALYSIS

The two estimates of travel distance were calculated for each trip and aggregated by ward. The seven 'key' socio-economic variables[1], identified in the previous chapter as strong predictors of average travel distance in the analysis of the National Travel Survey data, were also calculated for each ward. As with the examination of National Travel Survey data, stepwise regression was used to identify the extent to which these variables explain some of the differences in travel distance per person. Analysis of the data was carried out at the ward-level only since insufficient socio-economic data was collected in the surveys to carry out regression analysis at the individual level. The results of the regression analyses were compared against the results from the National Travel Survey data in order to test whether the results are similar to those from the two case study areas. In addition, the links between travel distance and other land use features such as the mixing of land uses and the proximity to the transport network were studied. The extent to which different areas conform to the results of the regression equation is then examined. Predicted values of travel distance for each ward were then calculated from the regression equation. Where the predicted values significantly differed from the estimated values, the travel patterns in these wards were examined in more detail. Other possible socio-economic and land use variables that could have an effect on

1. The seven 'key' socio-economic characteristics identified in the previous chapter as strong predictors of average travel distance are:
   (i) the average number of cars per person
   (ii) the proportion of households in socio-economic group 1 (professional and management)
   (iii) the proportion of households in socio-economic group 2 (intermediate and clerical)
   (iv) the proportion of households in socio-economic group 3 (skilled non-manual)
   (v) the proportion of households in socio-economic group 4 (semi-skilled manual)
   (vi) the proportion of households in socio-economic group 5 (unskilled manual)
   (vii) the proportion of persons in paid employment

average travel distance per person were then investigated using residual analysis in conjunction with interviews with professionals involved in transport and land use planning.

8.4.1 Socio-Economic Characteristics

The results of the regression analyses of travel data from Kent and Leicestershire indicate that the seven 'key' socio-economic variables alone account for more than half of the variation in average travel distance per person (around 70 per cent in Kent and 55 per cent in Leicestershire – see Appendix 10 and 12 for the regression equations in Kent and Leicestershire respectively). The effect of car ownership on travel distance is consistently very strong, with travel distance per person increasing as the level of car ownership increases. The results of the regression analyses show that household socio-economic status influences travel distance per person in all cases. In Kent and Leicestershire, travel distance per person is highest in areas where there is a large proportion of households in socio-economic groups 1 and 2 (professional/managerial, clerical/intermediate occupations). Conversely, travel distance per person is lowest in areas where there is a high proportion of households in socio-economic groups 4 and 5 (semi-skilled and unskilled manual occupations respectively). Travel distance is higher in areas where there is a large proportion of people in paid employment which is also consistent with the results of the analysis of the National Travel Survey data reported in chapter 7. The seven 'key' variables (identified in the previous chapter) explain more of the variation in distance per person per week in Kent than in Leicestershire (Table 8.5). In general, the results bear close resemblance to the results for Great Britain as a whole presented in chapter 7.

8.4.2 Land Use Characteristics

A summary and comparison of the results of the regression analyses of the Kent data using both estimates of travel distance ('straight-line' and 'journey-speed' distance) are presented in Appendix 10. Similar results from the regression analyses of the Leicestershire data are presented in Appendix 12 (the land use and socio-economic characteristics included in the analyses of the travel data from Kent and Leicestershire are identified in Appendices 9 and 11 respectively). The strengths of the partial regression coefficients from multiple regression are indicated according to the value of the beta weights ('standardised' partial regression coefficients). The larger the numerical value of the beta weight, either negative or positive, the greater its importance in accounting for the behaviour of the dependent term (Shaw and Wheeler, 1994 p.252). Conclusions from the regression analyses are drawn where the beta weight values show some consistency for both estimates of travel distance.

The association of average travel distance with land use characteristics such as job ratio and population density is similar in Kent and Leicestershire. Travel distance per person is higher in areas where the ward job ratio is low (less than 0.5 jobs per person) and lower in areas where the job ratio is high (more than 1.5 jobs per person). Ward densities between 40 and 50 persons per hectare are consistently associated with lower travel distances. Low-density wards on the other hand are associated with higher travel distances. However, ward densities above 50 persons per hectare are not associated with such low travel distances. Evidence from the analysis of the travel survey data from Kent also indicates a link between parking restraint and average travel distance per person – travel distance is lower in wards where there are parking restrictions. No conclusions have been reached about the effect of the proximity to the motorway or rail network since the evidence from the analysis of data from Kent and Leicestershire is not consistent. Evidence from Kent implies that travel distance is lower in areas close to the motorway network whereas evidence from Leicestershire suggests the opposite.

8.4.3 Interactions of Land Use and Socio-economic Characteristics

The extent to which land use and socio-economic characteristics explain the variation in travel distance per person is presented in Table 8.5. The seven 'key' socio-economic variables explain between 22 and 72 per cent of the variation in travel distance per person whilst land use characteristics explain between 5 and 48 per cent of the variation. The results from Kent and Leicestershire are quite consistent with each other and with the results from the analysis of the National Travel Survey data presented in chapter 7.

Slightly more of the variation in travel distance per person is explained in Kent than in Leicestershire. The coefficients of explanation (R^2 values) for the two regression equations for the Kent data are 0.72 and 0.69 while the coefficients of explanation for the two regression equations for the Leicestershire data are 0.55 and 0.56. The results show close correspondence between the two estimates of travel distance[1].

TABLE 8.5 SUMMARY OF REGRESSION ANALYSES FOR KENT AND LEICESTERSHIRE

	R^2 values			
Survey data →	*Kent*		*Leicestershire*	
Dependent variable → *Independent variables ↓*	*'Straight-line' distance per person per week*	*'Journey-speed' distance per person per week*	*'Straight-line' distance per person per week*	*'Journey-speed' distance per person per week*
All land use variables	0.48	0.47	0.43	0.35
All land use and 'key' socio-economic variables[2]	0.77	0.78	0.65	0.66
Seven 'key' socio-economic variables[3]	0.72	0.69	0.55	0.56
Range of effect of land use variables[4]	0.05-0.48	0.09-0.47	0.10-0.43	0.10-0.35
Range of effect of 'key' socio-economic variables[5]	0.29-0.72	0.31-0.69	0.22-0.55	0.31-0.56
Sample size (number of survey areas)	48	48	56	56

Sources: Survey data from Kent and Leicestershire.

The scatter of the predicted values (from the regression equation) and the actual values for the Kent and Leicestershire data are presented in Appendices 10 and 12 respectively (the R^2 values, the mean absolute deviation and the scatter plots indicate the goodness of fit of the regression equation).

1. The correlation coefficient between the between 'straight-line' distance and 'journey-speed' distance is 0.91 for the Kent data and 0.89 for the Leicestershire data. As would be expected, the 'straight-line' distance is lower than the 'journey-speed' distance, since the actual journey distance is almost always longer than the straight-line distance. Evidence from the Kent data suggests that the 'straight-line' distance is, on average, 9 per cent below the 'journey-speed' distance. Evidence from the Leicestershire data suggests that the 'straight-line' distance is 14 per cent below the 'journey-speed' distance. Thus, both sets of data show similar levels of correspondence between the results of the two methods for calculating journey distance and indicate that 'straight-line' distance perhaps underestimates actual travel distance by around 10 per cent (see Appendix 6).

2. All regression equations containing land use and socio-economic variables from the Kent travel survey data are presented in Appendix 10 and in Appendix 12 from the Leicestershire travel survey data.

3. All regression equations containing 'key' socio-economic variables from the Kent travel survey data are presented in Appendix 10 and in Appendix 12 from the Leicestershire travel survey data.

4. The R^2 value for the regression of all land use variables gives the upper value for the range of effect. The lower value for the range of effect is calculated by subtracting the R^2 value for the regression of the seven 'key' socio-economic and land use variables from the R^2 value for the regression of 'key' socio-economic variables.

5. The R^2 value for the regression of all socio-economic variables gives the upper value for the range of effect. The lower value for the range of effect is calculated by subtracting the R^2 value for the regression of the seven 'key' socio-economic and land use variables from the R^2 value for the regression of all land use variables.

8.5 RESIDUAL ANALYSIS

Two predicted values of travel distance for each of the wards in Kent and Leicestershire were calculated from the regression equations (using socio-economic and land use variables as the independent variables and the two values of total distance per person[1] as the dependent variables). Residual analysis was used to identify where there was a substantial difference between the predicted and observed values of travel distance (see section 6.2.3). The term 'hotspot' was used to describe an area where the observed value of travel distance was significantly higher than the predicted value and the term 'coldspot' was used to describe an area where the observed value of travel distance was significantly lower than the predicted value. Identification of hotspot wards was based on two criteria[2]:

relative residual > 0.2

&: standardised residual > 1.0

Thus, the observed value of travel distance must be at least 20 per cent higher than the predicted value and the standardised residual must be greater than 1.0 (indicating that the regression equation does not accurately predict variations in the dependent variables) to qualify as a hotspot ward. Similarly, identification of coldspot wards was based on the criteria[2]:

relative residual < -0.2

&: standardised residual < -1.0

Thus, the observed value of travel distance must be at least 20 per cent lower than the predicted value and the standardised residual must be less than -1.0 (also indicating that the regression equation does not accurately predict variations in the dependent variables) to qualify as a coldspot ward.

8.5.1 Hotspots and Coldspots

Only one hotspot ward (and no coldspot wards) were identified from the Kent data whilst four hotspots and seven coldspots were identified from the Leicestershire data (Table 8.6). With the exception of one ward in Kent, the predicted values of the travel distance for each ward

1. There are two values of journey distance since two methods for calculating distance were used (see Section 8.1).

2. The residual of both values of travel distance (i.e. the 'straight-line' distance and the 'journey-time' distance) must satisfy these conditions in order to be identified as a hotspot or a coldspot.

corresponded well with the observed values of travel distance. In Leicestershire on the other hand the predicted values of the travel distance for each ward did not correspond nearly so well with the observed values of travel distance in 11 of the 56 wards (20 per cent of the wards). Since there are a large number of hotspot and coldspot wards in Leicestershire, a more detailed examination of these wards was subsequently carried out in order to identify other socio-economic and land use reasons that may underlie the existence of these hotspots and coldspots. Details of this analysis are presented below.

TABLE 8.6 HOTSPOT AND COLDSPOT WARDS IDENTIFIED FROM RESIDUAL ANALYSIS

	Hotspot wards (observed travel distance is higher than predicted)	*Coldspot wards (observed travel distance is lower than predicted)*
Kent	• Frindsbury Extra	- - *none* - -
Leicestershire	• Birstall Goscote • Brookside • Groby • Latimer	• Birstall Greengate • Bradgate • Countesthorpe • Enderby • Grange • North Braunstone • Thurnby

Sources: Survey data from Kent and Leicestershire.

More detailed travel and socio-economic characteristics were then identified for each of the hotspot and coldspot wards in Leicestershire (Table 8.7). With the exception of Thurnby, the distance travelled per person in each of the coldspot wards is less than the average distance travelled per person in the 56 Leicestershire wards. Travel distance per person is above average in Thurnby but not as high as might be expected given the level of car ownership and employment in the area (which is why Thurnby is categorised as a coldspot ward). The distance travelled per person in each of the hotspot wards is greater than the average distance travelled per person in the 56 Leicestershire wards. Journey frequency is lower than average in most coldspot wards. Journey frequency in Groby is very close to the average for the 56 Leicestershire wards but the distance travelled per person in Groby is significantly higher than most wards, indicating that the average journey distance is higher than average.

TABLE 8.7 TRAVEL AND SOCIO-ECONOMIC CHARACTERISTICS OF THE HOTSPOT AND COLDSPOT WARDS IN LEICESTERSHIRE

	Ward	*Cars per person*	*Proportion of residents in employment (%)*	*'Straight-line' distance per person per week (km)*	*'Journey-speed' distance per person per week (km)*	*Journeys per person per week*
Coldspot wards (observed travel distance is lower than predicted)	Birstall Greengate	0.46	0.46	95	146	16.3
	Bradgate	0.51	0.51	108	129	15.2
	Countesthorpe	0.34	0.44	102	119	10.5
	Enderby	0.38	0.32	104	111	13.0
	Grange	0.61	0.52	126	149	12.4
	N. Braunstone	0.05	0.25	15	25	2.8
	Thurnby	0.74	0.56	163	180	16.9
Hotspot wards (observed travel distance is higher than predicted)	Birstall Goscote	0.33	0.39	162	193	19.4
	Brookside	0.41	0.38	211	228	18.3
	Latimer	0.30	0.35	137	174	16.7
	Groby	0.46	0.30	178	194	13.3
ALL 56 WARDS:		0.41	0.40	131	152	14.6

Source: Survey data from Leicestershire.

Travel distance by journey purpose for each of the Leicestershire hotspot and coldspot wards was tabulated (Table 8.8). Journey frequency is lower than average in four of the seven coldspot wards. The lowest journey frequency is in North Braunstone, where journey frequency is less than a fifth of the average. Most journey distances are very low in North Braunstone, where car ownership is extremely low (of the 12 households surveyed in this ward only one had a car). The distance travelled for work, education and escort purposes is lower than average in most coldspot wards whereas the average shopping distance in each ward is fairly similar. Travel to work distance in five of the coldspot wards (Birstall Greengate, Bradgate, Enderby, Grange and North Braunstone) is lower than average. The proportion of employed residents in Enderby and North Braunstone is low which would explain why work distance is low in these two wards. However, the proportion of residents in employment in Birstall Greengate, Bradgate and Grange wards is above average and does not therefore explain why travel to work distance in these three wards is lower than average.

TABLE 8.8 TRAVEL DISTANCE BY JOURNEY PURPOSE FOR EACH OF THE HOTSPOT AND COLDSPOT WARDS IN LEICESTERSHIRE

	Ward	*Distance per person per week (km) by purpose:*							*Journeys*
		All purposes	*Educa-tion*	*Escort*	*Shopping*	*Social/ Recreation*	*Work*	*Not specified* [1]	*per person per week*
Coldspot wards	Birstall Greengate	95-146	2-3	8-10	15-34	16-21	10-17	45-60	16.3
	Bradgate	108-129	3-5	6-7	16-21	14-21	17-18	50-59	15.2
	Countesthorpe	102-119	0	3-4	20-24	9-13	33-34	37-44	10.5
	Enderby	104-111	9	5	11	31-39	7-10	37-41	13.0
	Grange	126-149	1-2	4-6	13-16	26-30	9-11	69-89	12.4
	N. Braunstone	15-25	0	0	5-8	1-4	2	7-12	2.8
	Thurnby	163-180	1-2	8	31-34	29-33	18-19	76-85	16.9
Hotspot wards	Birstall Goscote	162-193	11-14	13-14	21-28	14-15	30-35	69-92	19.4
	Brookside	211-228	5-8	11-18	13-19	29-36	44-67	79-111	18.3
	Latimer	137-174	0	9	20-21	36-39	21-35	51-71	16.7
	Groby	178-194	3-4	19-32	10-14	18-34	45-60	65-68	13.3
All 56 wards		131-152	5	8-10	16-22	22-23	23-24	57-68	14.6

Source: Survey data from Leicestershire.

Journey frequency is higher than average in three of the four hotspot wards. Travel to work distance is higher than average in most of the hotspot wards. Escort journeys are higher than average in Brookside and Groby although car ownership and the proportion of employed residents is near average. Travel to work distance in three of the hotspot wards (Birstall Goscote, Brookside and Groby) is higher than average whilst car ownership and the proportion of employed residents is close to the average in these wards. Car ownership is relatively low in Latimer but the total distance travelled per person is above average (which is why Latimer is categorised as a hotspot ward). The distance travelled for social/recreation purposes in Latimer is higher than average and the journey frequency in Latimer is also above average.

Having identified these detailed socio-economic and travel characteristics in each of the hotspot and coldspot wards (Tables 8.7 and 8.8), discussions were held with professionals involved in land use and transport planning in the Leicestershire area to identify some of the other reasons that might underlie the trends. A number of additional socio-economic and land use reasons were suggested in the interviews as possible reasons for the results behind the trends (Table 8.9). These socio-economic and land use characteristics are discussed below.

1. The purpose of some journeys recorded in the Kent and Leicestershire travel data were unspecified and a journey purpose could not therefore be allocated.

TABLE 8.9 POSSIBLE REASONS FOR THE EXISTENCE OF HOTSPOT AND COLDSPOT WARDS IN LEICESTERSHIRE

Type of characteristics	*Possible characteristic that might explain the existence of hotspot and coldspot wards*
Socio-economic	Income Ethnic group Lifestyle, attitudes and interests Employment type Social networks (friends and family)
Land use	Fast links to employment centres outside the city Availability and frequency of public transport Large local employers or large employment centres Local shops and other facilities

8.5.2 Additional Socio-Economic Characteristics

The relationships between a large number of socio-economic characteristics and travel distance were examined earlier in the study (see chapter 7). However, the examination of socio-economic characteristics was clearly limited to those characteristics recorded in the National Travel Survey. Thus, the relationships between some socio-economic characteristics and travel distance were not examined. Discussions with land use and transport planning professionals in Leicestershire identified additional socio-economic characteristics that may underlie the travel trends in the hotspot and coldspot wards. These characteristics include income, ethnic group, lifestyle, attitudes and interests, employment type and social networks.

Income is clearly an important determinant of the availability of private transport and the propensity to travel. The relationship between income and travel distance was not examined using the National Travel Survey data, although the relationship between car ownership and travel distance was examined. This is likely to be similar since household income is a proxy for car ownership (see chapter 7). However, it could be that household income and car ownership may have similar but slightly different effects on travel distance. The issue of poverty was highlighted by a number of interviewees as a possible reason underlying the very low number of journeys and the low travel distance in North Braunstone, an area with a high level of poverty and social deprivation.

Ethnic group was suggested as a second reason that may affect travel distance. Latimer ward for example has a large proportion of residents of Asian origin. The level of car ownership and employment in the ward would suggest lower than average travel distance per person whereas travel distance and journey frequency is slightly above average. Journey distance is significantly higher than average for social and recreation purposes in Latimer than in Leicester as a whole. One reason for the results may be that minority ethnic groups travel further to see friends or family or for other social and recreation activities. This is also closely linked to the discussion about the closeness of social networks (see below).

A third socio-economic characteristic that may contribute to the travel trends is the broad category of lifestyle, attitudes and interests which is likely to significantly influence travel distance. The characteristic may affect one or more journey purposes. The category covers a range of issues which are likely to be interlinked with other socio-economic characteristics such as level of education, income, age and employment type. For example, Brookside and Birstall Goscote wards were identified as areas of relatively modern housing where ‘car culture’ (high car ownership and use) may be more prevalent than in other locations. On the other hand, Grange ward was identified as a ward in which residents may have ‘greener’ attitudes and may chose to use the car less even though car ownership is relatively high.

Employment type is also likely to affect travel distance. Issues such as the specialisation of a person’s employment and the extent to which a person has to travel as part of their work are clearly important determinants of travel distance. Employment type is likely to be linked to household socio-economic group. This was examined earlier in the study and a strong link with travel distance was found (see chapter 7). Grange ward for example contains a large number of persons employed at the city’s two universities which may have some bearing on the low travel to work distance (university employees may sometimes work at home).

Finally, the closeness of social networks (in terms of friends and family) is likely to influence travel patterns. The extent to which friends and family are distributed across the city and beyond is clearly likely to affect travel distance, particularly social and recreation travel. Close social networks in North Braunstone were suggested as a reason for low social and recreation travel although low income and low levels of car ownership in the ward are likely to contribute to the closeness of these networks. In contrast, it was suggested that residents of Latimer ward may have a wide social network, perhaps due in part to ethnic reasons and therefore travel further than average to see friends or family or take part in other social or recreation activities.

8.5.3 Additional Land Use Characteristics

The relationships between certain land use characteristics and travel distance have been examined using data from the National Travel Surveys (chapter 7) and data from local travel surveys in Kent and Leicestershire (earlier in this chapter). The land use characteristics already examined include population density (at the ward and district levels), settlement size, job ratio, the distance to high street shops, the proximity to the bus, rail and main road network, the frequency of bus services and the availability of parking. Discussions with land use and transport planning professionals in Leicestershire identified other land use characteristics that may underlie the travel trends in the hotspot and coldspot wards. These characteristics include access to employment centres outside the city, the availability and frequency of public transport, the proximity of large local employers or large employment centres and the proximity of local shops and other facilities. The possible effects of each of these characteristics on travel distance are discussed in turn below.

Travel distance per person may be higher than average in locations which have fast links to employment centres outside the city. These locations are often close to the edge of the city where travelling into the city centre may be more congested and time consuming than travelling out of the city to more distant employment centres. Birstall Goscote for example is north of the city centre and adjacent to the A6 which gives access to a wide range of job opportunities further north of Leicester (in Loughborough for example). Brookside ward is similar to Birstall Goscote in that it is also on the outskirts of Leicester and close to the A6, providing access to job opportunities to the south-east of the city (in Market Harborough for example). Groby is also on the edge of the city of Leicester and is close to junctions 21A and 22 of the M1 motorway, providing access to job opportunities further north and south of the city and also to south-west of the city via the M69 motorway.

It was suggested in the discussions with land use and transport planning professionals in Leicestershire that the infrequency of public transport might explain why travel is lower than expected in certain coldspot wards. It was speculated that in areas where public transport frequency is relatively low, as in Bradgate ward for example, fewer journeys are possible for people without access to a car which therefore reduces the average travel distance per person. The link between travel distance per person and the frequency of bus services or the distance to the nearest bus stop was not examined using the data from Kent or Leicestershire but evidence from the analysis of data from National Travel Surveys suggests the reverse of this effect. Analysis of data from National Travel Surveys suggest that the further people live from a bus stop and the lower the frequency of the bus service the longer the average travel distance (see chapter 7).

A third land use characteristic that may contribute to the variation in travel patterns is the proximity of large local employers or large employment centres. To some extent this is related to job ratio but only where local employment is in the same ward. The job ratio does not provide a measure of local employment centres that are close but not within the ward. It has been reported earlier in the chapter that average travel distance is consistently higher in areas where there is a low job ratio (less than 0.5 jobs per worker) which would imply that travel distance is lower in areas where employment and population is more balanced. It is also likely that average travel distance is lower in areas that are proximate to large local employers or large employment centres. Countesthorpe for example is close to GEC, a large local employer. Similarly, Enderby is close to the main offices of the Next Group and Grange is close to the headquarters of the Alliance and Leicester bank in Narborough.

Finally, the proximity of local shops and other facilities is likely to affect travel distance. The results from the analysis of data from National Travel Surveys suggest that average travel distance is lower in areas that are close to local facilities (see chapter 7). This is also likely to be the case in Kent and Leicestershire although this relationship was not examined statistically due to limitations of the data from these local surveys. It was suggested in discussions with land use and transport planning professionals in Leicestershire that one of the reasons for lower travel in wards such as Countesthorpe, Thurnby and Birstall Greengate is the proximity of local shops and other facilities which contribute to greater self-containment in these wards and reduce the need for long journeys for some activities.

8.6 SUMMARY

This chapter has analysed travel data from Kent and Leicestershire using similar regression analyses to those carried using National Travel Survey data in the previous chapter. The purpose of these analyses was firstly to test whether the results from the National Travel

Survey data were similar to those from local surveys in the case study areas and secondly to examine the effect of other land use characteristics not recorded in the National Travel Surveys. The chapter has investigated the links between selected socio-economic characteristics, a number of land use variables and travel distance per person.

There are a number of differences between travel surveys from Kent and Leicestershire (the size, date and time period of the surveys for example) but they are nevertheless similar enough to make some comparisons and analyse in a similar way. Similar distances are travelled per person per week for most journey purposes in Kent and Leicestershire. Average travel distance in the Kent case study area is close to the national average. In the Leicestershire study area, average travel distance is lower than the national average. Three journey purposes (work, shopping and social/recreation) account for a large proportion of the total distance travelled. A greater proportion of the total travel distance is work-related in Kent than in Leicestershire, perhaps because the Kent data relates to weekday travel, whereas the Leicestershire data also includes weekend travel.

The results of the regression analyses of travel data from Kent and Leicestershire showed that the seven 'key' socio-economic variables alone account for more than half of the variation in average travel distance per person (more in Kent than in Leicestershire). The link between car ownership and travel distance is very strong: travel distance per person increases as the level of car ownership increases. The results of the regression analyses show that the link between household socio-economic status and travel distance per person is also quite consistent. Travel distance per person is highest in areas where there are large numbers of households in socio-economic groups 1 and 2 (professional/managerial, clerical/intermediate occupations). Conversely, travel distance per person is lowest in areas where there is a high proportion of households in socio-economic groups 4 and 5 (semi-skilled and unskilled manual occupations respectively). Travel distance is higher in areas where there is a large proportion of people in paid employment which is also consistent with the results of the analysis of the National Travel Survey data.

Of the land use characteristics examined in Kent and Leicestershire, ward-level density and job ratio are linked with distance per person in both case study areas. Two other land use characteristics are linked with distance per person in one of the case study areas: the proximity to a railway station and limited residential parking. Average travel distance is higher in areas with low ward-level population density (less than 10 persons per hectare) and lower in areas with a population density between 40 and 50 persons per hectare. Travel distance per person is lower in areas where the job ratio is high (more than 1.5 jobs per person). In Leicestershire, travel distance per person is higher by between 11 and 12 kilometres per person per week in areas that are close to a railway station. The link between the proximity to the motorway network and travel distance per person is unclear from the analysis of data from Kent and Leicestershire. Contradictory results emerge from the two surveys. Evidence from Kent shows that travel distance per person is lower by up to 7 kilometres per person per week in areas where there is a residential parking scheme (similar analysis was not carried out in Leicestershire because there are no residential parking schemes in the case study area).

The seven 'key' socio-economic variables explain between 22 and 72 per cent of the variation in travel distance per person whilst the land use characteristics explain between 5 and 48 per cent of the variation. The results from Kent and Leicestershire are quite consistent with each other and with the results from the analysis of the National Travel Survey data. Slightly more of the variation in travel distance per person is explained in Kent than Leicestershire. The coefficients of explanation (R^2 values) for the two regression equations for the Kent data are 0.72 and 0.69 while the coefficients of explanation for the two regression equations for the Leicestershire data are 0.55 and 0.56. The results show close correspondence between the two estimates of travel distance ('straight-line' and 'journey-speed' distance).

Two predicted values of travel distance for each of the wards in Kent and Leicestershire were calculated from the regression equations obtained using socio-economic and land use variables as the independent variables and total distance per person as the dependent variables. Wards where there was a substantial difference between the predicted and observed values of travel distance were then identified. The term 'hotspot' was used to describe an area where the observed value of travel distance was significantly higher than the predicted value while the term 'coldspot' was used to describe an area where the observed value of travel distance was significantly lower than the predicted value. Residual analysis was used to identify these hotspots and coldspots.

Only one hotspot ward (and no coldspot wards) were identified from the Kent data whilst four hotspots and seven coldspots were identified from the Leicestershire data. With the exception of one ward in Kent, the predicted values of the travel distance for each ward were found to correspond well with the observed values of travel distance. In Leicestershire on the other hand, the predicted values of the travel distance for each ward did not correspond nearly so well with the observed values of travel distance in 11 of the 56 wards examined. Since there are a large number of hotspot and coldspot wards in Leicestershire a more detailed examination of these wards was subsequently carried out in order to identify other socio-economic and land use reasons that may underlie the existence of these hotspots and coldspots.

Discussions were held with professionals involved in land use and transport planning in the Leicestershire area to identify some of the other socio-economic and land use characteristics that had not been investigated in the study but which might underlie the travel trends. A number of additional reasons were suggested as possible reasons for the results behind the trends. These include socio-economic characteristics such as income, ethnic group, lifestyle, attitudes and interests, employment type (as opposed to socio-economic group) and the closeness of social networks (both friends and family). Land use characteristics that were suggested as possible reasons for the results behind the trends include the proximity (in terms of time and/or distance) to employment centres outside the city, the availability and frequency of public transport, the proximity of large local employers or large employment centres and the proximity of local shops and other facilities. Two of these, namely the frequency of public transport and the proximity of local shops, correspond with characteristics that were identified as being linked to travel distance per person in the analyses of National Travel Survey data presented in chapter 7.

CHAPTER 9: SYNTHESIS OF RESULTS

This chapter assesses the results from the national and local travel surveys presented in the previous two chapters and compares their findings. It suggests how individual, household and land use characteristics may affect travel distance on the basis of evidence from national and local travel data. The chapter identifies the implications of the results for land use planning and discusses the extent to which land use planning may reduce travel and hence the environmental impacts of transport. The implications are discussed in relation to current government policy planning guidance. Synergies and conflicts between different land use characteristics are discussed with a view to identifying mutually reinforcing planning policies. The chapter identifies where elaboration and modification of planning policy guidance may assist the formulation and introduction of land use policies to reduce the need to travel.

9.1 THE INFLUENCE OF SOCIO-ECONOMIC CHARACTERISTICS ON TRAVEL PATTERNS

The links between socio-economic characteristics and travel distance were mainly explored using National Travel Survey data since only a limited amount of socio-economic information was collected in the Kent and Leicestershire travel surveys. It was possible however to use data from the Kent and Leicestershire surveys examine some links between socio-economic characteristics and compare with the findings from the analysis of National Travel Survey data. Two types of socio-economic characteristics are distinguished, namely characteristics of the *individual* (such as gender, employment status and age) and characteristics of the *household* (such as household socio-economic group, car ownership and household composition).

9.1.1 Individual Characteristics

The analyses of National Travel Survey data reveal that there are substantial variations in travel distance according to the characteristics of the individual. These characteristics include gender, age, work status and the possession of a driving licence. Men travel further than women on average. People aged between 30 and 39 travel more than most other age groups on average. People in full-time work travel most whilst those in part-time work or not in work travel the least. At the survey area level of analysis, residents of areas containing high proportions of people in work travel most whereas residents of areas containing low proportions of people in work travel least. People with a driving licence travel further than those with only a provisional licence and those without a licence. These observations come from the analysis of data at the individual level (in regression analyses of travel distance with socio-economic and land use characteristics for each *person*). There is no evidence for links between travel distance and the distribution of these characteristics at the survey area level of analysis (in regression analyses of average travel distance with socio-economic and land use characteristics for each *survey area*) with the exception of work status. This may be due to the fact that there is little variation in these characteristics across different areas (or, in other words, most areas have broadly similar proportions of men and women, young and old, drivers and non-drivers).

9.1.2 Household Characteristics

Analyses of National Travel Survey data reveal that there are also links between a number of characteristics of the household and travel distance. These characteristics include socio-economic group, household car ownership and household composition. Residents of households in socio-economic groups 1 and 2 (professional/managerial and intermediate/ clerical non-manual) travel further than residents of households in socio-economic groups 3, 4 and 5 (skilled, semi-skilled and unskilled manual respectively). Travel distances are highest in areas where there is a high proportion of households in socio-economic group 1 and lowest in areas where there is a high proportion of households in socio-economic groups 3, 4 and 5. People in households with two or more cars travel the most whilst residents of households without a car travel the least. Residents of areas with high car ownership travel most whilst the residents of areas with low car ownership travel least. In terms of household type, the residents of households containing two adults and no children (and where the head of the household is under 30 years old) travel more than residents in most other categories of household composition.

From the large number of socio-economic variables examined from the National Travel Survey data, seven variables provide a reasonable prediction of average travel distance per person at the survey area level of analysis. The seven 'key' variables are:

(i) the average number of cars per person
(ii) the proportion of households in socio-economic group 1 (professional and management)
(iii) the proportion of households in socio-economic group 2 (intermediate and clerical)
(iv) the proportion of households in socio-economic group 3 (skilled non-manual)
(v) the proportion of households in socio-economic group 4 (semi-skilled manual)
(vi) the proportion of households in socio-economic group 5 (unskilled manual)
(vii) the proportion of persons in paid employment.

These seven variables consistently explain over one third of the variation in travel distance at the survey area level of analysis (using the National Travel Survey data). The seven variables explain more of the variation in travel distance per person from 1985/86 onwards. The seven variables also explain over half of the variation in travel distance in both Kent and Leicestershire. It is clear that socio-economic characteristics often explain a large proportion of the variation in travel patterns across different areas. These results are consistent with research by Gordon (1997) who reports that a third of the variation in per capita transport energy consumption is attributable to socio-economic factors. The results are also reasonably consistent with research by Goodwin (1995) who reports that socio-economic factors such as income are responsible for more of the variation in car use than location. The results correspond with the findings of McDougall and Mank (1982) who report that high transport energy consumers (in Canada) come from larger households with high income levels and high levels of car ownership.

9.2 The Influence of Land Use Characteristics on Travel Patterns

The results from the analyses of data from the four National Travel Surveys indicate stable links over time between many land use characteristics and travel distance per person. Evidence from National Travel Surveys indicates that land use characteristics explain up to 27 per cent of the variation in travel distance per person at the survey area level of analysis. The results of the analysis of local travel data which suggests that land use characteristics explain up to 48 per cent of the variation in travel distance in Kent and up to 43 per cent of the variation in Leicestershire. More of the variation in travel distance is consistently explained by socio-economic characteristics however. Evidence for the link between various land use characteristics and travel distance is presented below.

9.2.1 Distance from the Urban Centre

There is no clear evidence of a link between the distance from the urban centre and travel distance per person. The research does not confirm the findings of Næss et al (1995) or Curtis (1995) who report a link between the distance from the urban centre and travel distance per person (see chapter 3). However, it should be made clear that the measure of distance between home and the urban centre used in this study is not the same as the measures used by either Næss et al or Curtis which may explain the difference of results. In this study the distance between home and the urban centre was measured in terms of the journey time by foot to the nearest high street shops. It is recognised that the measure may not accurately reflect the proximity to the nearest urban centre since high street shops are not always found in central urban areas (they are also found in out of town shopping centres and along the radial routes of larger cities for example). However, the measure does indicate the degree or 'urbanity' or 'rurality' of a location and does not appear to be strongly linked with travel distance per person.

9.2.2 Settlement size

Analysis of National Travel Survey data at individual level provides no strong evidence of a link between settlement size and travel distance. However, analysis at the individual level of analysis suggests that average travel distance is often lower in London and other large urban areas containing more than 250,000 residents by up to 43 kilometres per person per week. The link between settlement size and travel distance was not explored using data from Kent and Leicestershire since few settlement sizes were included in these two surveys. The research results on settlement size accord to some extent with the research of ECOTEC (1993), which suggests a link between settlement size and travel distance per person. The settlement size associated with lowest travel distance per person identified in this research is different to the settlement size reported by ECOTEC (1993) however. This research suggests that average travel distance is consistently lower in London and large urban areas containing more than 250,000 residents. ECOTEC (1993) on the other hand suggest that travel distance is lowest in large metropolitan areas (excluding London). ECOTEC do not control for the effects of socio-economic or land use characteristics on travel distance per person however. One of the planning implications of these observations is that new development might be directed into London and large urban areas with over 250,000 residents or where there is the potential to increase the population above this figure. The current approach to housing allocation broadly reflects this idea where the preferred location of new residential development is in existing towns and cities although there is no guidance on settlement size except for advice against new developments of less than 10,000 dwellings in PPG13 (see chapter 4). Eight categories of settlement size were used in the analysis. The two categories at the lower end of the scale (0-3,000 and 3,000-25,000 residents) cover a large population range and a large number of settlements. Unfortunately it is not possible to classify this group into narrower categories from the available National Travel Survey data. It is likely that could be substantial differences in land use and travel characteristics in settlements of 3,000 residents and settlements of 25,000 residents.

9.2.3 The Mixing of Land Uses

Evidence from the Kent travel survey suggests that travel distance per person is lower by as much as 44 kilometres per person in areas where the job ratio is high (more than 1.5 jobs per person). Travel distance is higher in areas where the job ratio is low (fewer than 0.5 jobs per employable person) than in other areas. Evidence from the Leicestershire travel data suggests that travel distance per person is lower by up to 13 kilometres per person per week in areas where the job ratio is high. Clearly, higher job ratios are associated with lower travel distance. However, it is not possible to achieve high job ratios in all areas (since this would require a surplus of jobs or a deficit of employable residents). There are a number of possible options for managing job ratios such as:

- the equal distribution of jobs according to the distribution of local labour, resulting in a balance between jobs and employable residents in all areas (equal job ratios)
- the complete centralisation of jobs, resulting in a few areas with very high job ratios and the remainder with low job ratios
- a less centralised distribution of jobs where some employment is centralised (such those requiring specialised professions) whilst other employment is distributed across all other

areas, resulting in a narrower spread of job ratios than the complete centralisation option, where the job ratio of all areas are reasonably balanced (between 0.5 and 1.5 jobs per employable resident).

The first option (the equal distribution of jobs) might promote more short journeys and more of an equalisation of travel distances but could also lead to diffuse travel patterns which is problematic for public transport operation. The second option for employment distribution (involving the centralisation of jobs) might lead to more convergent travel patterns that are more conducive to public transport operation but might also result in the lack of local employment activities and few opportunities for short journeys. The third option (less centralised distribution of jobs) may avoid excessive segregation of employment and residential land use, resulting in more convergent travel patterns that are more conducive to public transport operation and the increased opportunity for short journeys through the provision of local employment. The measure of mixed land use used in this study (job ratio) clearly only relates to the mixing within the ward and does not indicate for example how mixed land uses are in adjacent areas.

9.2.4 The Provision of Local Facilities

Analysis of National Travel Survey data at individual level provides no clear evidence of a link between travel distance and the proximity to local facilities. However, analysis at the survey area level suggests that average travel distance is shorter by up to 46 kilometres per person per week where the proximity to local facilities (defined in terms of the nearest post office, chemist and grocers) are all within a three-minute walk from home. The link between the proximity to local facilities and travel distance was not explored with the data from Kent and Leicestershire since information concerning local facilities was not collected in these two surveys. Action to stimulate the provision of local facilities might be enhanced through agreements with developers (such as section 106 agreements under the 1993 Town and Country Planning Act). Development in high-density clusters around local facilities is likely to increase their local 'catchment' (as proposed by Barton et al, 1995).

9.2.5 The Density of Development

Most analyses of travel data in this study suggest a link between ward-level population density and travel distance. Local authority population density on the other hand does not appear to have a strong link with travel distance per person. Residents of low-density wards (under 10 persons per hectare) travel longer distances than the residents of other wards by as much as 25 kilometres per person per week. The results from the National Travel Surveys on the link between population density and travel distance correspond well with the results from Kent and Leicestershire. Evidence from National Travel Survey data and the local travel surveys in Kent and Leicestershire indicate that travel is lowest in areas where population density is between 40 and 50 persons per hectare. However, travel distance may not be as low in areas where the population density is above 50 persons per hectare. The evidence therefore suggests that low population densities are likely to be associated with high travel distance per person. There is some evidence to tentatively suggest that there may be a critical ward-level population density of 40 to 50 persons per hectare, at which travel distance is lowest and above which travel distance may increase. Evidence from ECOTEC (1993) suggests that travel distance per person decreases fairly steadily as population density increases without an upper threshold although the ECOTEC study does not control for the effects of socio-economic or other land use characteristics on travel distance per person which might explain the difference of results. Limiting development at excessively low or high densities is one way of reducing the environmental impact of transport through land use planning. This may be practically achieved through planning guidance or government circular. The imposition of minimum and maximum residential densities by local planning authorities is possible under the current planning policy framework although few authorities impose maximum standards (Breheny and Archer, 1998). Where local planning authorities do have maximum residential density standards most are below the level of 40 to 50 persons per hectare (ibid.). It should be noted that achieving an overall ward-level density of 40 to 50 persons per hectare requires concentrations of development *above* this density if other types of development[1] and other land uses[2] are also to be provided in the ward (necessary conditions for mixed land use development and local services and facilities).

1. Other types of development include shops, offices and schools.
2. Other types of land uses include parks, gardens and footpaths.

9.2.6 The Proximity to Main Transport Networks

Analyses of national travel data at the individual level and survey area level suggests that average travel distance per person is higher by up to 40 kilometres per person in areas where the local bus frequency is low (fewer than 2 buses per hour). However, the implication is not necessarily that increased bus frequency would reduce travel distance. The effect may even be the reverse: travel distance might increase if the local bus frequency is increased. It may also be the case that more frequent public transport might be linked to decisions about car ownership (and hence car use). Because bus frequencies are often low in remote areas, higher travel distance could be as much a consequence of remoteness as much as the availability and frequency of public transport. Thus, it may be preferable to increase bus frequencies to encourage the use of alternative modes to the car as a way of reducing congestion and emissions but it is unclear whether increasing bus frequency will reduce travel distance. The location of development in areas with high bus frequencies may be a reason to reduce parking provision which might indirectly lead to less travel (see section 9.3). Evidence from the analysis of the interaction between car ownership, land use and socio-economic characteristics (in section 7.3.4) indicates a link between car ownership and bus frequency.

There is little evidence of a link between the proximity to a railway station and travel distance from the analysis of National Travel Survey data at the individual level or the survey area level of analysis. Analysis of the Kent travel data does not give any clear results about the effect of proximity to a railway station on travel distance, whilst the analysis of travel data from Leicestershire suggests that the proximity to a railway increases travel distance by up to 12 kilometres per person per week. As in the case of locations with high bus frequencies, it may be possible to reduce parking provision in locations close to a railway station which might indirectly lead to less travel (see section 9.3). It is apparent from the analysis of the interaction between car ownership, land use and socio-economic characteristics that there is a link between car ownership and the proximity to a railway station (see section 7.3.4).

The link between travel distance and the proximity to a motorway junction was not examined using the National Travel Survey data since no information concerning the proximity to a motorway was collected in these surveys. Analysis of the travel data from Kent suggests that travel distance per person is in areas that are closer to a motorway junction, which clearly does not support the hypothesis that average travel distance per person increases as the proximity to the main road network increases. Evidence from Leicestershire on the other hand suggests the reverse of this observation. Travel distance per person is higher by up to 109 kilometres per person per week in areas that are closer to the motorway network, which is more in line with the results of Headicar and Curtis (1994) reported in chapter 3.

9.2.7 The Availability of Residential Parking

The link between travel distance and the availability of residential parking was not examined using the National Travel Survey data since no information concerning parking availability was collected in these surveys. Only the travel data for Kent was examined to explore the link between travel distance and parking provision since there were no residential parking schemes in operation in Leicestershire at the time of the travel survey. Evidence from Kent indicates that travel distance per person is lower by up to 7 kilometres per person per week in areas where there is a residential parking scheme. Thus, the evidence suggests that limited residential parking may reduce travel distance. It may be that there are both direct and indirect effects. The limited availability of parking may lead to more 'rational' car use as residents seek to reduce the number of journeys and hence the number of times they have to search for a parking space on their return home. Limited residential parking may also indirectly contribute to less travel by suppressing car ownership which this study identifies as a strong determinant of travel distance (see section 7.3). Balcombe and York (1993) however suggest that difficulties in finding a parking space may not necessarily deter car ownership or intentions to acquire additional vehicles. They report that even with intensified parking problems, vehicle acquisition may exceed the rate of disposal. A survey by Balcombe and York (1993) in areas with limited residential parking showed that 18 per cent of residents in intended to acquire an additional car within a year and only 10 per cent of residents would consider getting rid of their vehicle if the parking situation worsened[1].

9.2.8 Comment

The links between individual land use characteristics and travel distance per person are summarised in Table 9.1. The summaries are derived from the regression equations from the analyses of the National Travel Survey data at the individual and survey area levels and from

1. It is not clear, however, what proportion of the residents who intended to acquire an additional car also intended to move house during that time, which is an important influence on plans to acquire a car.

the analyses of the Kent and Leicestershire travel survey data. The results show similarities with research by Gordon (1997), who reports that around one third of the variation in per capita transport energy consumption is attributable to land use characteristics and another third of the variation in per capita transport energy consumption is attributable to socio-economic factors. The results are also reasonably consistent with research by Goodwin (1995) who reports that socio-economic factors such as income are responsible for more of the variation in car use than location. However the results of this study do not support Goodwin's conclusions that location and accessibility are only important for the least car dependent sections of society and are unimportant for the rest. Evidence from this study indicates that although land use characteristics might not affect travel distance as much as socio-economic characteristics they are still important influences on travel distance. They may be more important if they are combined with other land use characteristics and/or supported by complementary policy measures (see section 9.4). Land use characteristics may also influence car ownership and hence have an indirect effect on travel distance (see section 9.3).

TABLE 9.1 SUMMARY OF EVIDENCE FROM NATIONAL AND LOCAL DATA

Data source → *Level of analysis* → *Main land use characteristics* ↓	*National Travel Survey* *Individual level*	*National Travel Survey* *Survey area level*	*Kent data* *Ward-level*	*Leicestershire data* *Ward-level*
1. Distance from the urban centre	No evidence of a link between travel distance and the distance to the urban centre at the individual or survey area level of analysis.		Not tested.	Not tested.
2. Settlement size	No evidence of a link between settlement size and travel distance at the individual level of analysis.	Average travel distance is consistently lower in London than in smaller settlements by up to 43 kilometres per person per week. Residents of large urban areas containing more than 250,000 residents travel less than the residents of most other sizes of settlement.	Not tested.	Not tested.
3. The mixing of land uses	Not tested.	Not tested.	Travel distance per person is lower by up to 13 kilometres per person per week in areas where the job ratio is high (more than 1.5 jobs per person).	Travel distance per person is lower by up to 44 kilometres per person per week in areas where the job ratio is high (more than 1.5 jobs per person).
4. The provision of local facilities	No evidence of a link between travel distance and the proximity to local facilities at the individual level of analysis	Average travel distance is shorter by up to 46 kilometres per person per week in areas close to local facilities (i.e. where the nearest post office, chemist and grocers are all within a three-minute walk from home).	Not tested.	Not tested.

TABLE 9.1 SUMMARY OF EVIDENCE FROM NATIONAL AND LOCAL DATA [CONTINUED]

Data source → *Level of analysis* → *Main land use characteristics* ↓	*National Travel Survey* *Individual level*	*National Travel Survey* *Survey area level*	*Kent data* *Ward-level*	*Leicestershire data* *Ward-level*
5a. The density of development – local authority density	No evidence of a link between travel distance and local authority population density at the individual or survey area level of analysis.		Not tested.	Not tested.
5b. The density of development – ward-level density	Residents of low-density wards (under 10 persons per hectare) travel longer distances than the residents of most other wards. Low ward-level density (less than 10 persons per hectare) adds between 8 and 25 kilometres to the total distance travelled per person per week.	Average travel distance is higher by up to 14 kilometres per person in areas with low ward-level population density (less than 10 persons per hectare) with the exception of evidence from the data for 1978/79.	Average travel distance is higher by up to 5 kilometres per person in areas with low ward-level population density (less than 10 persons per hectare) and up to 16 kilometres per week lower in areas with a population density between 40 and 50 persons per hectare (travel distance is higher in areas with a population density above 50 persons per hectare).	Average travel distance is between 27 and 35 kilometres per week lower in areas with a population density between 40 and 50 persons per hectare (travel distance is higher in areas with a population density above 50 persons per hectare).
6a. Proximity to the main transport network – bus stop	No evidence of a link between travel distance and the proximity to a bus stop at the individual or survey area level of analysis.		Not tested.	Not tested.
6b. Proximity to the main transport network – bus frequency	Residents of areas with lower bus frequencies (fewer than two buses every hour) travel longer distances. The link with bus frequency has increased over time. In 1978/79 there was little difference in travel distance between the residents of areas with different bus frequencies. In 1991/93, however, residents of areas with lower bus frequencies travelled 40 kilometres more than residents of areas.	Average travel distance per person is higher by up to 35 kilometres per person in areas where the local bus frequency is low (fewer than 2 buses per hour). Car ownership (and perhaps consequently travel distance per person) is higher in areas with low frequency bus services (fewer than 2 per hour).	Not tested.	Not tested.

TABLE 9.1 SUMMARY OF EVIDENCE FROM NATIONAL AND LOCAL DATA [CONTINUED]

Data source → *Level of analysis* → *Main land use characteristics* ↓	*National Travel Survey* *Individual level*	*National Travel Survey* *Survey area level*	*Kent data* *Ward-level*	*Leicestershire data* *Ward-level*
6c. Proximity to the main transport network – railway station	No evidence of a link between proximity to a railway station and travel distance at the individual level of analysis.	No evidence of a link between proximity to a railway station and travel distance at the survey area level of analysis. However, car ownership (and perhaps consequently travel distance) is lower in areas within a 6-minute walk from the nearest railway station (which is approximately equivalent to half a mile)	Unclear results.	Travel distance per person is higher by up to 12 kilometres per person per week in areas close to a railway station.
6d. Proximity to the main transport network – motorway junction	Not tested.	Not tested.	Travel distance per person is lower by up to 13 kilometres per person per week in areas adjacent to the motorway network.	Travel distance per person is higher by up to 109 kilometres per person per week in areas adjacent to the motorway network.
7. The availability of residential parking	Not tested.	Not tested.	Travel distance per person is lower by up to 7 kilometres per person per week in areas where residential parking is restricted (by means of a residential parking scheme).	Not tested.

9.3 LAND USE CHARACTERISTICS AND CAR OWNERSHIP LEVELS

The results from the analyses of data from the four National Travel Surveys indicate that the car ownership is consistently the strongest predictor of travel distance. Hence, land use characteristics associated with low car ownership may indirectly affect travel distance. Evidence from National Travel Surveys indicates that land use characteristics explain up to 37 per cent of the variation in the level of car ownership. Two of the more important land use characteristics linked with car ownership are the proximity to a railway station and the frequency of the local bus service. Car ownership is higher in areas with low frequency bus services (fewer than 2 per hour) and in areas further than a 6-minute walk from the nearest railway station (which is approximately equivalent to half a mile). The availability and frequency of public transport may clearly influence household decisions about the need for a car. Limited residential parking may also reduce car ownership and consequently travel distance.

It is feasible to expect that certain land use characteristics might influence car ownership and hence travel distance. Thus, land use characteristics such as the effects of the proximity to a railway station and the frequency of the local bus service might also be considered as potential (indirect) levers to reduce travel distance. The evidence for the links between the proximity to a railway station, the frequency of the local bus service and car ownership suggests that locations which might suppress car ownership are those within reach of frequent public transport. Such locations are most likely to be urban or interurban on transport corridors since other locations are less likely to be able to support frequent public transport. Current planning policy guidance on transport and land use (PPG13) supports the principles of urban development and the proximity to frequent public transport. Thus, the land use characteristics that might act to reduce car ownership are already in place although not quantified. Were PPGs to include more quantified guidance, issues such as the meaning of 'proximate', 'well-served' and 'frequent' would need to be elaborated. For example, planning guidance could specify that preferred locations for new development are areas that are or will be served by frequent bus services (more than 2 per hour) and that are or will be within a 6-minute walk from the nearest railway station (within half a mile).

9.4 THE POLICY IMPLICATIONS

Some of the land use characteristics associated with less travel may be complementary with others. On the other hand, some may be in conflict with others or may be in conflict with other goals of sustainability. This section discusses the potential areas of synergy and conflict between these land use characteristics. It identifies other possible complementary measures and examines the compatibility of the land use characteristics with current land use planning policy guidance.

9.4.1 Synergies and Conflicts

Some of the main areas of synergy and conflict between the land use characteristics associated with less travel are summarised below and illustrated in Figure 9.1.

FIGURE 9.1 SYNERGIES AND CONFLICTS BETWEEN LAND USE CHARACTERISTICS

✓ represents potential synergy
✗ represents potential conflict

	Settlement Size	Local Facilities	Population Density	Mixing of Land Uses	Bus Frequency	Railway Station Proximity
Local Facilities	✓ or ✗					
Population Density		✓ or ✗				
Mixing of Land Uses		✓	✗			
Bus Frequency	✓		✓			
Railway Station Proximity	✓		✓		✓	
Availability of Parking		✓ or ✗	✓	✗	✓	✓

In general, the larger the population of a settlement, the greater the number of local facilities that can be supported. From a self-containment point of view there is therefore an argument for settlements with populations large enough to support a wide range of facilities (which is the basis for population thresholds for different local facilities suggested by Barton et al, 1995). However, higher settlement sizes do not necessarily encourage the provision of additional local facilities, particularly where the friction of distance is low (because of high mobility and low travel costs for example). There may instead be an increased reliance on existing facilities. In smaller settlements this may mean that few local facilities and services can be supported and in larger settlements this may mean that the nearest services and facilities are in distant parts of the settlement. There is therefore a need to address issues of mobility and travel cost if facilities are to be provided locally and travel distances are to be minimised. Settlement size may also affect the level of public transport provision. In general, the larger the population of a settlement, the greater the number of public transport services that can be supported. Larger settlements are clearly more able to support frequent bus services and a railway station.

Higher population densities may encourage the provision of local facilities by increasing the number of residents living nearby. Excessively high housing density standards may however lead to residential areas being designed to maximise density at the expense of other types of development (including local facilities) unless policies to promote mixed use are also in place. Mixed-use developments may also increase the market and provision of local facilities by virtue of the number of workers or visitors coming into the area. The availability of residential parking may also affect the provision of local facilities. Residents of areas where residential parking is limited may prefer to use local facilities to avoid using the car and a long search for a parking space on their return home. The providers of local services and facilities, particularly private-sector providers, may be discouraged from locating in an area with limited parking because there is the perception that there will be fewer users. Thus, there is also a potential conflict between policies to restrict parking and policies to promote mixed land uses.

Higher population density provides a larger potential market for public transport and is therefore complementary to public transport provision (Barton et al, 1995 illustrate how higher development density around bus stops might be used to maximise convenience and accessibility to public transport). Lower provision of residential parking allows more homes to be accommodated per unit area and is hence complementary with increases in development density. Balcombe and York (1993) report that higher densities may also encourage more efficient use of parking spaces and hence reduce the costs of providing parking.

Limited residential parking is complementary with the increased provision of public transport. Limited availability of parking may suppress car ownership and/or use, enhance the use of public transport and increase the frequency of public transport services. Greater use of public transport is more conducive to the provision of additional bus and rail routes and more railway stations.

Putting together all the land use characteristics associated with less travel would suggest that the most sustainable urban form from a travel reduction perspective is one composed of large, high-density, mixed-use settlements containing a range of local facilities with frequent, convenient public transport services. In terms of overall urban development, these characteristics are compatible with strategies of inner city compaction, high-density corridor development and urban nodal development but not compatible with strategies of suburban expansion and unmanaged dispersal. Of the three compatible strategies, Newton (1997) concludes that two strategies, namely high-density corridor development and urban nodal development, are likely to provide greater air quality benefits[1].

In terms of resource consumption, these characteristics might minimise land loss and promote energy efficiency. Higher densities decrease the amount of land required for new development and provide the necessary conditions for more energy-efficient construction and combined heat and power schemes (see for example Owens, 1986). Higher densities may however prevent the use of passive solar designs since they rely on development that is not overshadowed.

Achieving the land use characteristics associated with less travel may also have impacts on other issues of sustainable development such as regional development, urban green-space and quality of life[2]. Regional development may be affected by the concentration of economic activity in urban areas. Rural development may decline as the concentration of development in existing urban areas reduces economic activity in rural areas (Newby, 1990). Increases in urban density and settlements size may run counter to the provision of urban green-space unless specific policies for the provision of green-space are part of the planning process.

1. Air quality impacts were measured in terms of exposure to both smog and particulates and compared to current and forecast (business as usual) levels.

2. A more detailed account of various negative impacts of urban compaction on issues of sustainable development is contained in Breheny (1992b).

Strategies for high-density corridor development and urban nodal development may be compatible with increases in urban population density and population size and the provision of urban green-space. This is the approach adopted for managing development in the Leicestershire through a strategy of 'green wedges' (Leicestershire County Council, 1994). Public opinions and preferences do not correspond with certain land use characteristics associated with less travel such as higher densities and large settlements (see section 9.5.2). Achieving more sustainable land use patterns may therefore sometimes run counter to quality of life issues.

9.4.2 Complementary Measures

There is a range of policy levers available to reduce the environmental impacts of transport. Planning policies are one type of policy lever (see section 2.4). Other types of levers include economic instruments, legislation and regulation. A variety of these might be used to support and enhance the effect of land use measures associated with less travel. This section explores the ways in which several different types of measures may be used to promote the land use characteristics associated with less travel which have been identified in this study. Examples of complementary measures include:

- Parking charges and restrictions
- Vehicle and fuel taxes
- Road and congestion charging
- Reduction of road-space
- Public transport priority measures
- Restrictions in car access
- Greenfield land tax
- Derelict land grants

The effects of each of these measures on the land use characteristics associated with less travel are indicated in Table 9.2. Most of the complementary measures are likely to influence not just a single land use characteristic but a number of characteristics. Some of the measures may promote certain land use characteristics but make others more difficult to achieve. Road and congestion charging for example might promote more self-contained settlements, more local facilities and the mixing of land uses but may on the other hand discourage development in areas where congestion is most severe and encourage development outside the areas affected by road or congestion charging. This may then lead to increased urban sprawl. Road or congestion charging may also act as a disincentive for some people to live or work in urban areas and increasing the demand for smaller rather than larger settlements.

Location policies for one type of development may affect location decisions for other types of development. Employment location policies based on the type of development and its accessibility profile may for example affect residential location decisions. Similarly, shopping location policies based on accessibility profiles may also help to shape residential location decisions.

Complementary measures to promote the land use characteristics identified in this study associated with less travel therefore need to be carefully selected to avoid possible conflicts with other land use characteristics. The introduction of policy packages rather than single measures may prevent some conflicts between other measures and certain land use characteristics. Haughton and Hunter identify the need to maximise the synergies between different policy instruments as most important in the development of policies to relieve urban transport problems (Haughton and Hunter, 1994 p.283). Carrot and stick measures introduced together may avoid possible conflicts associated with individual measures. Strategic environmental assessment of development plans may improve the coordination of land use and transport policies (see for example Thérivel et al, 1992; Thérivel and Partidário, 1996; or Thérivel, 1998).

TABLE 9.2 LAND USE CHARACTERISTICS AND COMPLEMENTARY MEASURES

Land use characteristics → *Complementary measures ↓*	*Larger settlement size*	*Provision of local facilities*	*Higher population density*	*Mixing of land uses*	*Higher bus frequency*	*Railway station*	*Limited residential parking*
1. Parking charges and restrictions	✓ May discourage the use of the car. ✗ May discourage housing and employment development in areas affected by parking charges or restrictions.	✓ May promote the provision of local facilities in residential areas ✗ May discourage private-sector provision of local services and facilities in areas affected by parking charges or restrictions.	✓ May suppress car ownership and reduce the demand for car parking space and consequently allow for higher density development.	✓ May promote the mixing of land uses in residential areas.	✓ May discourage car use in areas affected by parking charges or restrictions and encourage the use of public transport. Higher bus frequencies may then be profitable.	✓ May discourage car use in areas affected by parking charges or restrictions and encourage the use of public transport. Additional rail services may then be profitable.	✓ Parking charges may reduce the demand for residential parking.
2. Vehicle and fuel taxes	✓ May discourage residential locations far from work, shops, schools, etc.	✓ May encourage more self-contained settlements with more local services and facilities.	✓ May make higher density living more attractive.	✓ May encourage more self-contained settlements with mixed land use.	✓ May discourage car use, encourage public transport and help support higher bus frequencies.	✓ May discourage car use, encourage public transport and help support additional railway stations.	✓ May suppress car ownership, use and the demand for car parking.
3. Road and congestion charging	✗ May discourage development in areas where congestion is most severe and encourage development outside the areas affected by road or congestion charging.	✓ May encourage more self-contained settlements with more local services and facilities.	✓ May make higher density living more attractive for some. ✗ May discourage others to live or work in urban areas.	✓ May encourage more self-contained settlements with mixed land use.	✓ May discourage car use and promote public transport and help support higher bus frequencies.	✓ May discourage car use, promote public transport and help support additional railway stations.	✓ May suppress car ownership, use and the demand for car parking.

TABLE 9.2 LAND USE CHARACTERISTICS AND COMPLEMENTARY MEASURES [CONTINUED]

Land use characteristics → *Complementary measures ↓*	*Larger settlement size*	*Provision of local facilities*	*Higher population density*	*Mixing of land uses*	*Higher bus frequency*	*Railway station*	*Limited residential parking*
4. Reduction of road-space	✗ May discourage development in areas where congestion is most severe and encourage development outside the areas affected by road or congestion charging.	✓ May encourage more self-contained settlements with more local services and facilities.	✓ May make higher density living more attractive.	✓ May encourage more self-contained settlements with mixed land use.	✓ May discourage car use, promote public transport and help support higher bus frequencies.	✓ May discourage car use, promote public transport and help support additional railway stations.	✓ May suppress car ownership, use and the demand for car parking.
5. Public transport priority measures	✓ May increase the attractiveness of living in larger settlements with good public transport services.	✗ May not encourage self-containment or the provision of local services and facilities.	✓ May increase the attractive-ness of living in higher densities with good public transport services.	✗ May not encourage self-containment or mixed use development.	✓ May improve the speed of public transport, increase patronage and help support higher bus frequencies.	✓ May increase public transport patronage and help support additional railway stations.	✓ May suppress car ownership, use and the demand for car parking.
6. Restrictions on car access	✗ May discourage development in areas where car access is restricted and encourage development outside the areas affected by access restrictions.	✓ May encourage more self-contained settlements with more local services and facilities.	✓ May increase the attractiveness of living in higher densities if land uses are mixed.	✓ May encourage more self-contained settlements with mixed land use.	✓ May increase public transport patronage and help support higher bus frequencies.	✓ May increase public transport patronage and help support additional railway stations.	✓ May suppress car ownership, use and the demand for car parking.
7. Greenfield land tax and derelict land grants	✓ May encourage development in existing settlements and increase settlement size.		✓ May encourage higher density development.				✓ Greenfield land tax may reduce plot sizes and parking provision.

9.5 Obstacles, Barriers and Responsibilities for Sustainable Land Use Planning

Evidence from this research suggests that a number of land use characteristics are linked with travel distance. These include settlement size, the mixing of land uses, the provision of local facilities, the density of development and the frequency of public transport. Other land use characteristics that may also be linked to travel distance include the proximity to a railway station, the proximity to a motorway and the availability of residential parking. The research also suggests that public transport frequency and the proximity to a railway station may also be linked with car ownership which in turn is linked to travel distance. This section examines some of the barriers to the introduction of these issues into land use planning decisions and focuses on three main types of barrier: economic, public opinion and preferences, institutional and organisational barriers.

9.5.1 Economic Barriers

There may be a number of economic reasons for the difficulty in introducing certain land use characteristics into land use planning decisions even though they may be associated with less travel. First, local authorities may resist higher job ratios for commercial reasons. They may argue that giving priority to development in areas currently lacking in employment may lead to employers locating elsewhere with detrimental consequences for local employment. These commercial pressures on local authorities often mean that authorities do not feel able to be unduly stringent in imposing planning conditions to reduce traffic. Second, developers currently favour development in rural rather than urban locations for economic reasons. Greenfield sites are often cheaper and easier to acquire and develop. There is often a lack of certainty about the funding for land remediation on previously developed sites and concern over future legal liabilities (Banister, 1998b). Third, there is also reluctance on the part of financial institutions to invest in anything other than low financial risk development (see for example Cadman and Topping, 1995 pp.124-132) which results in conservative decisions about density, parking provision and location. Fourth, increasing car ownership and use affects the economics of public transport provision. It reduces the profitability of public transport, leads to higher prices and poorer provision and adds to the cycle of higher car ownership and use. Uncertainty over the funding of public transport and other green modes makes planning agreements concerning these modes more difficult to introduce or enforce. Gorham (1998) argues that less sustainable land uses are encouraged by distortions in the property market. Because low-density, detached homes are more likely to hold and increase their value than flats or apartments, there is a high demand for less-dense, less sustainable development[1]. Gorham argues that mortgage relief also distorts the property market and increases the demand for low-density development by encouraging the purchase of larger, higher value property than would have been possible without mortgage relief. Competition between local government may also act to increase the attractiveness of less sustainable locations, particularly where transport costs are low. Council tax is often higher in urban areas which may encourage urban depopulation to neighbouring authorities without necessarily reducing the use of urban facilities, services and infrastructure.

9.5.2 Public Opinion and Preferences

Public opinion and preferences are often the reasons quoted by property developers for housing outside urban areas and/or at lower densities. Negative attitudes about cities in terms of pollution, crime, privacy and open space are some of the reasons for people choosing to live outside urban areas in lower-density housing (see The Housebuilders Federation, 1997 for example). The attraction of town centres and high streets as places to live is currently limited. As car ownership and use has increased and the cost of travel has fallen the location of homes in relation to work, recreation and education has become progressively less important. There are some very strong advantages to urban living such as lower travel times and convenient shopping which fewer people appear to value as much as other issues (such as pollution, crime, privacy or open space). Urban environmental, social and economic problems are often exacerbated by people escaping from them, especially when people move to more remote areas but still rely on the city for most activities. There is consequently a spiral of decline in urban attractiveness as rural migration occurs. Many of the external costs of this migration are often passed on to the urban residents.

1. Less dense development is often in less sustainable locations because it is usually found in smaller settlements, where public transport services are infrequent, local facilities are few and car parking is generous.

9.5.3 Institutional and Organisational Barriers

A number of institutional and organisational barriers exist to the introduction of certain land use characteristics into land use planning decisions. First is the multiplicity of interests involved in providing new development which may lead to the uncoordinated or incomplete provision of local services, facilities or employment opportunities. The separation of professional responsibilities leads to divisions in planning and transport arrangements and the separation of planning into plan making and implementation (Banister, 1998b). A second related issue is the fragmentation of the organisation, integration and management of public transport which may lead to uncoordinated or incomplete provision of public transport. There is also scepticism about the effectiveness of various land use policy measures to reduce travel (Banister, 1998b). There may also be a lack of knowledge and understanding of land use and transport issues by councillors and officers and doubts whether certain matters can be considered in planning decisions. Lack of institutional cooperation to properly integrate land use and transport policies is a further barrier to making more coherent and sustainable decisions. The integration of the three institutions formerly responsible for the environment, land use planning and transport planning at the national level into a single government department (the Department of the Environment, Transport and the Regions) is a step towards more integrated decision-making (although staff from the three policy areas still remain in separate divisions). Similar reorganisation of responsibility has taken place at a local level with many local authorities integrating environment, land use planning and transport planning within a single department. This integration does not guarantee inter-sectoral collaboration or decision-making however and there is still often a strong divide between the activities of local authority transport planners and town planners. The long-term nature of issues concerning sustainable development (and transport is crucial to many aspects of sustainable development) are often given less importance in decision-making at the expense of shorter-term goals, especially where decision-makers are in post for a limited time period or where practitioners have no long-term stake.

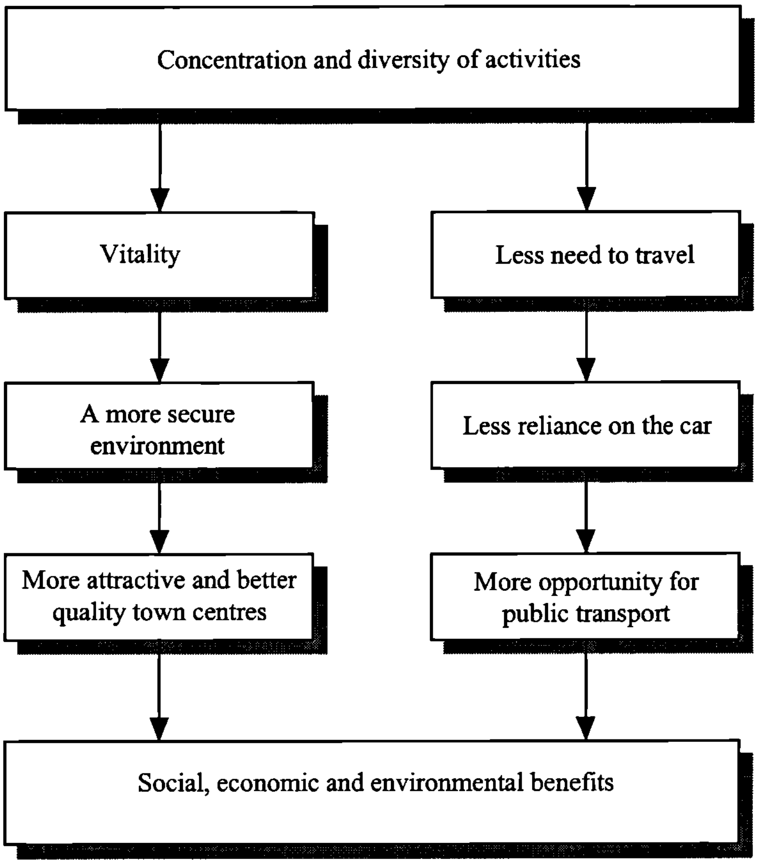
9.5.4 Overcoming Barriers and Obstacles to Sustainable Land Use Planning

Overcoming the barriers identified above requires concerted action using a combination of economic and regulatory levers, training and education and awareness campaigns. The issue of barriers and obstacles to the introduction of more sustainable land use policies is an area where little research has been conducted. If barriers and obstacles to the introduction of certain policies are to be overcome, more work needs to be done to identify the components of successful strategies. These components might include consideration of the role of inter-sectoral working, the timing of policy introduction, the packaging of measures and the involvement of stakeholders in the policy-making process for example.

Some of the strong driving forces that have led to less sustainable trends in land use (such as the spiral of increasing car ownership leading to more expensive and less frequent public transport) require strong action to reverse them. Economic measures must be used to equalise the costs of public and private transport which have diverged over the last two decades and internalise the external costs of transport. Other complementary measures including land use planning policies must be used in combination with economic measures to move from a vicious circle of transport and land use policies to a virtuous circle of measures. Bringing together mutually reinforcing land uses (see section 9.4.1) and complementary policies (see section 9.4.2) provides a powerful combination of measures that may contribute to economic, social and environmental benefits (Figure 9.2). High quality design is crucial to the successful introduction of policies to promote the land use characteristics associated with less travel that have been identified in this study.

Informing and challenging public opinion and preferences to highlight the benefits to sustainability of higher densities, urban living and lower car ownership and use may be needed for certain land use changes to be accepted. Action at the local and national level to tackle the causes of people moving away from more sustainable locations or lifestyles may begin to overcome some of the barriers relating to public opinion and preferences. The combination of measures identified above (Figure 9.1) may assist this action.

FIGURE 9.2 THE BENEFITS OF COMBINING COMPLEMENTARY LAND USE AND TRANSPORT MEASURES



Source: Department of the Environment (1995).

9.5.5 Actions for More Sustainable Policies

The introduction of more sustainable land use planning policies requires action at several different levels of decision-making. At the *national level*, action is required to:

- introduce changes to planning policy guidance to provide more detail on how policies can reduce the need to travel by for example setting out standards for minimum densities or the provision of local services and facilities
- require planning authorities through planning guidance and funding appraisal to give greater priority to the implementation of policies that are likely to lead to land use characteristics associated with less travel
- introduce policies in other sectors that are likely to be complementary to more sustainable planning policies (such as parking charges and restrictions, vehicle and fuel taxes, road

and congestion charging, reduction of road-space, public transport priority measures, greenfield land tax – see section 9.4.2)

- require the environmental appraisal of development plans to identify in more detail any potential conflicts and synergies between policies

At the *regional* and *strategic level,* action is required to:

- focus development that attracts trips in existing centres or locations that are well served by public transport
- limit development outside existing urban areas where accessibility by public transport is poor and cannot easily be improved
- improve public transport accessibility through better provision
- equalise or reduce large differences in parking standards at different locations to prevent excessive development in locations with lower parking standards

At the *local* and *neighbourhood level,* action is required to:

- raise the density of development at or around locations with high public transport accessibility, such as public transport corridors
- increase the mixing of development and the provision of local services and facilities through section 106 agreements
- utilise sites with good public transport accessibility or capable of being well served by public transport
- limit development in locations outside urban areas and/or poorly served by public transport
- use high quality design to increase the attractiveness of high-density urban development
- locate development in existing urban areas as much as possible to increase settlement size

9.6 SUMMARY

This chapter has assessed the results from the national and local travel surveys presented in the previous two chapters and compared their findings. The chapter has suggested how individual, household and land use characteristics may affect travel distance on the basis of evidence from national and local travel data. The implications of the results for land use planning and the extent to which land use planning may reduce travel have been discussed, particularly in relation to current government policy planning guidance. The chapter has identified where elaboration and modification of planning policy guidance may assist the formulation and introduction of land use policies to reduce the need to travel. The chapter has examined some of the barriers to the introduction of these issues into land use planning decisions and the ways in which these barriers might be overcome.

The results of the study indicate that a number of individual characteristics (such as gender, age, employment status and the ability to drive) explain the variation in travel distance at an individual level. However, individual characteristics do not have much consistent influence on travel distance per person at the survey area level of analysis. The results of the study also show that a number of household characteristics explain the variation in travel distance. These include characteristics such as the socio-economic group, the proportion of people in employment and household car ownership. These seven variables consistently explain over one third of the variation in travel distance. Socio-economic characteristics often explain a large proportion of the variation in travel patterns across different areas. Research into land use and travel patterns must recognise these links and find ways of standardising for these effects.

The study demonstrates stable links over time between many land use characteristics, socio-economic factors and travel distance. Evidence from the study indicates that land use characteristics consistently explain less of the variation in travel distance per person than socio-economic characteristics but suggests that land use characteristics are still likely to influence travel patterns significantly. Land use characteristics explain up to 48 per cent of the variation in travel distance whilst socio-economic characteristics explain up to 72 per cent of the variation. In general, analyses from this study suggest that around half of the variation in travel distance can be explained by socio-economic characteristics and one quarter of the variation can be explained by land use characteristics.

The research suggests that a number of land use characteristics are linked with travel distance and consequently transport emissions. These include settlement size, job ratio, local facilities, population density and public transport frequency. Other land use characteristics that may also be linked to travel distance include the proximity to a railway station, the proximity to a motorway and the availability of residential parking. The research also suggests that public transport frequency and the proximity to a railway station may also be linked with car ownership which in turn may be linked to travel distance. Most of these issues are already included in planning policy guidance although most are expressed only as principles and there is little quantification or elaboration of criteria on which to base planning decisions.

There are a number of barriers to the introduction of these issues into land use planning decisions. These include barriers concerning financial, public opinion and preferences, institutional and organisational issues. Overcoming these barriers requires concerted action using a combination of economic and regulatory levers, training and education and awareness campaigns. The issue of barriers and obstacles to the introduction of more sustainable land use policies is an area where little research has been conducted and needs to be investigated further. More work needs to be done to identify the components of successful strategies if barriers and obstacles to the introduction of certain policies are to be overcome. Some of the strong driving forces that have led to less sustainable trends in land use (such as the spiral of increasing car ownership leading to more expensive and less frequent public transport) require strong action to reverse them. Other complementary measures including land use planning policies must be used in combination with economic measures to maximise the effect of land use measures. Bringing together mutually reinforcing land and complementary policies provides a powerful virtuous combination of measures that may contribute to economic, social and environmental benefits. Coordinated action is required at a number of different levels of decision-making to introduce more sustainable planning policies.

CHAPTER 10: CONCLUSIONS

This study contributes to the understanding of land use and transport interactions in several main ways. In particular, the study has:

- reviewed a wide selection of literature not only concerning the interaction of land use and travel patterns but also concerning socio-economic characteristics and travel patterns
- compiled and compared the findings of a range of other empirical studies carried out over the last 20 years from across the world (mainly in Western Europe and the United States) and from a diverse set of literature sources
- identified a number of potential indicators of travel patterns and examined how well they represent environmental impacts of transport such as atmospheric emissions – some travel patterns were found to be reasonable proxies for transport emissions and useful environmental indicators of travel
- developed a method of residual analysis for the study of the interactions between travel patterns, socio-economic and land use characteristics
- shown how residual analysis might be used to explore the variation of travel patterns in different locations using 'hotspot' and 'coldspot' analysis
- examined links between travel patterns and a large number of socio-economic and land use characteristics by carrying out more thorough empirical analyses than in many other studies
- carried out empirical analysis at different levels using data from several sources to explore the level of analysis most appropriate to the exploration of the links between travel patterns, socio-economic and land use characteristics
- identified the importance of different land use characteristics and examined the extent to which they are complementary or in conflict
- shown that many land use characteristics are complementary, although there are cases in which there are potential conflicts between certain land uses and cases of certain land use characteristics that may conflict with other objectives of sustainable development
- identified a number of complementary measures that might support the introduction of land use characteristics associated with less travel

- identified actions across different levels of decision-making that might promote more sustainable land use decisions and identified some important barriers and obstacles to the implementation of land use policies that might promote more sustainable travel patterns

10.1 THE ENVIRONMENTAL IMPACTS OF TRANSPORT

The study has identified and quantified many of the important environmental impacts associated with transport, ranging from local through to global in scale. It has shown that some of these impacts are increasing, whilst others are set to increase at some stage in the future unless action is taken to reduce transport growth. It has shown that transport's contribution to pollution in urban areas is particularly high. The study maintains that technology has the potential to curb some of these impacts but asserts that it may not be sufficient alone because transport growth is increasing faster than improvements in technology.

The study has identified the need for a range of policy measures to tackle the environmental impacts of transport in order to fulfil current international, national and local environmental targets. A variety of measures are available to tackle these environmental impacts. These include fiscal policies, technology, education and regulation. All are important ways of reducing the environmental impacts of transport. Many of these measures may reinforce each other.

The study has shown that past land use policies have been responsible for some of the growth in transport. Economic and demographic trends have also been strong driving forces behind transport growth. The reversal of these trends requires equally strong and coordinated action. Land use planning is one way of tackling the environmental impacts of transport growth. It is a long-term strategy that will not achieve results quickly but is arguably more politically acceptable than many other types of policy (economic policies for example) that might be used to achieve similar outcomes. Furthermore land use planning offers a way of tackling some of the causes (rather than the effects) of transport demand. Land use planning policies are robust under a variety of futures and may help to reduce social inequalities. A variety of land use characteristics may affect transport demand. This study has examined links between travel patterns and a number of these land use characteristics. The characteristics examined in the study include settlement size, the availability of local services and facilities, population density, the mixing of land uses, the proximity of public transport and the availability of parking.

10.2 THE REVIEW AND CRITIQUE OF OTHER STUDIES

The study has shown that a large number of studies have focused on the link between one or more of the above land use characteristics and travel patterns. These studies have involved a number of different research methods and a variety of data sources. The results of many of these studies are broadly in agreement although there is still strong debate about the role of land use characteristics in influencing travel. Proponents suggest that the variations in travel patterns across different areas are primarily due to land use reasons. Opponents suggest that the variations in travel patterns are mainly due to economic and social reasons rather than land use differences, arguing that different land uses are populated by different socio-economic groups and it is this difference in social and economic characteristics which explains the variation in travel patterns. Others assert that both explanations may be valid and suggest that the various influences on travel demand may be interlinked.

The review of other studies has shown that increasing distance from home to the urban centre is often associated with increasing travel distance, an increasing proportion of car journeys and increasing transport energy consumption. However, trip frequency does not vary significantly according to the distance between home and the urban centre.

The review has found a relatively large amount of research concerning the relationship between settlement size and travel patterns. The relationship between settlement size and travel patterns is unlikely to be simple due to the interplay of competing factors. Evidence from Great Britain shows that large metropolitan settlements are associated with low travel distance and transport energy consumption. However, evidence from the ten largest urban areas in the United States shows no easily identifiable relationship between urban population size and modal choice.

The review has found relatively few studies concerning the effect of land use mix on travel patterns such as the effect of job ratio. There is little consensus on the effect of land use mix on travel patterns although it is likely that land use mixing might contribute to lower travel demand through the decentralisation of less specialised employment.

The review has shown that there is broad consensus about the effects of local facilities and services on travel patterns. The provision of local facilities may contribute to less travel overall but is not necessarily more conducive to less energy intensive modes such as walking and cycling.

The review has identified a growing body of research that suggests a link between population density and many measures of travel patterns. However, there is little evidence of much variation in journey frequency by population density. In contrast to the amount of research into the relationship between population density and travel patterns, there has been little recent research concerning the relationships between employment density and travel patterns.

The proximity to transport networks also influences travel patterns and consequently transport energy consumption. Better access to major transport networks, particularly road and rail networks, increases travel speeds and extends the distance which can be covered in a fixed time. Major transport networks can be a powerful influence on the dispersal of development – both residential and employment development. The proximity to major transport networks may lead to travel patterns characterised by long travel distances and high transport energy consumption.

The review has shown that the availability of residential car parking is linked to both trip frequency and modal choice according to a limited amount of research evidence. The evidence suggests that the proportion of car journeys increases as the availability of residential car parking increase.

The review reveals that many other studies only consider the role of one or two land use characteristics rather than a wide range of characteristics. Most do not consider the role of socio-economic characteristics and their influence on travel patterns. The few studies that do include socio-economic characteristics do not consider a very wide range of different social and economic factors that may affect travel patterns. There has been little research into the temporal aspects of land use and travel linkages (i.e. how the effects of land use on travel may have changed over time). Comparisons between various studies are not always possible due to differences in spatial units used for analysis and different ways of measuring travel patterns.

10.3 TRAVEL PATTERNS AS ENVIRONMENTAL INDICATORS

Because there are many different measures of travel patterns it is often difficult to compare the findings of different studies. Rather than using a large number of different measures of travel patterns and environmental impacts, this study has used a single indicator of travel patterns which is representative of the environmental impacts of travel. This study has identified a number of potential indicators of travel patterns and examined how well they represent environmental impacts of transport such as atmospheric emissions. Some travel patterns were found to be reasonable proxies for transport emissions and useful environmental indicators of travel. The selection of a suitable indicator involved the comparison of different measures of travel patterns and environmental impacts using National Travel Survey data. This comparison showed that aggregated transport energy consumption per person and total travel distance per person are most representative measures of travel patterns as indicators of per capita atmospheric emissions from transport. Measures of travel patterns such as the travel distance by car, the travel time by car, the total non-work distance by all modes and the travel time by all modes are all reasonable indicators of transport emissions but are less representative than transport energy use or travel distance. Some measures of travel patterns (such as total work distance by all modes, the number of journeys by car and the average journey distance by all modes) are less adequate indicators of transport emissions. Other measures of travel patterns (such as average journey time by all modes, proportion of journeys made by car, the number of journeys by all modes, the number of journeys by cycle, the proportion of journeys made by cycle, the number of journeys by public transport, the proportion of journeys made by public transport, the number of journeys by foot and the proportion of journeys made by foot) are poor indicators of transport emissions.

Two methods of calculating transport energy consumption have been examined. The 'simple' calculation of energy consumption only took account of mode and distance whilst the 'complex' calculation of energy consumption also took account of a range operating conditions including occupancy, vehicle age, fuel type, engine temperature, travel speed and engine size. Both measures were found to be very similar to each other and very representative of most atmospheric emissions from transport.

The results of this part of the research provides an input to the current search for sustainability indicators at the national and local level (see for example Local Government Management Board, 1994 and Department of the Environment, Transport and the Regions, 1998e). The results also provide researchers with information about the suitability of different measures of travel patterns as environmental indicators of transport.

10.4 Conceptual Approach and Research Methods

Travel distance per person has been used as the measure of travel patterns for use in this study because it is a simple, readily available indicator and is representative of the atmospheric environmental impacts of transport. Although a reasonable proxy for transport emissions, total travel distance per capita does not illustrate the distribution and dispersion of transport pollutants within a neighbourhood, city or region. This would require more detailed information about journey times and routes as well as topographical and climatic data. Travel distance may not be an accurate indicator of some of the other main impacts of transport such as community severance or noise and vibration although the trends in these impacts may follow the same direction as trends in travel distance.

The design and execution of the study has taken into account many of the weaknesses of other studies and has incorporated ways of overcoming them wherever possible. The strengths of the study include a more exhaustive approach to identifying potential links between land use, socio-economic characteristics and travel patterns than in previous studies. The study has examined the potential links between a large number of socio-economic characteristics and a variety of different land use characteristics. It has examined changes in these links over time to identify whether there is a temporal dimension to these links. It has employed data from both the national and local level and has analysed them at the individual level and at the survey area level.

The measures of land use characteristics used in this study have been quantitative and sometimes quite simple. The study has not included qualitative or more complex composite measures of land use characteristics such as quality of life or 'liveability' because although important there is no agreed way of identifying them (and there is little information from the travel surveys to try to construct such a measure). These 'softer' measures are likely to influence the socio-economic profile of an area and possibly local travel patterns. Future studies might try to examine the potential links between these more qualitative characteristics, travel patterns and socio-economic characteristics (see section 10.8).

Residual analysis has been used to identify wards where there were large differences between predicted and calculated vales of travel distance. Only one residual ward in Kent was identified whereas 11 wards were identified in Leicestershire. It may be that there are fewer other socio-economic and land use characteristics that influence travel distance in Kent than in Leicestershire. Interviews with land use and transport professionals in Leicestershire have helped to identify other socio-economic and land use characteristics that may affect travel distance in these residual wards.

The data from the Kent and Leicestershire travel surveys have shown that there is consistency between the two methods for estimating travel distance. The results of the regression analyses using the two estimates of travel distance were very similar, implying that both methods for estimating journey distance provide similar results.

10.5 THE INFLUENCE OF SOCIO-ECONOMIC CHARACTERISTICS ON TRAVEL PATTERNS

Analysis of national and local travel data has shown that socio-economic characteristics are consistently strongly associated with travel distance per person. Seven key socio-economic characteristics are particularly useful in predicting travel distance per person at the survey area level:

(i) the average number of cars per person
(ii) the proportion of households in socio-economic group 1 (professional and management)
(iii) the proportion of households in socio-economic group 2 (intermediate and clerical)
(iv) the proportion of households in socio-economic group 3 (skilled non-manual)
(v) the proportion of households in socio-economic group 4 (semi-skilled manual)

(vi) the proportion of households in socio-economic group 5 (unskilled manual)

(vii) the proportion of persons in paid employment

Thus travel distance is very much influenced by class, car ownership and employment. Although related, the seven key socio-economic variables are not multicollinear. Car ownership is consistently the strongest determinant of travel distance per person. In addition to being related to class and employment, the study has shown that car ownership is likely to be related to land use characteristics such as the proximity to public transport routes and the availability of residential parking (see below).

More of the variation in distance per person is explained by the seven key socio-economic variables at the survey area level than at the individual level. To some extent this is a function of the large amount of data analysed at the individual level and less at the survey area level (the larger the number of cases, the lower likelihood of a high coefficient of explanation in regression analysis). The regression analysis of the National Travel Survey data included more than 20,000 cases at the individual level and around 700 (aggregated) cases at the survey area level. More of the variation in travel distance per person is explained by socio-economic characteristics in the analyses of more recent National Travel Survey data, indicating that socio-economic characteristics may be increasingly important determinants of travel. Analysis of the data from Kent and Leicestershire has confirmed the findings from the National Travel Survey data that the seven key socio-economic characteristics are important determinants of travel distance.

In addition to the large number of socio-economic characteristics that were examined in this study, interviews with transport and land use professionals have helped to identify several other socio-economic characteristics that may influence travel distance. These include income, ethnic group, lifestyle, attitudes and interests, employment type (as opposed to socio-economic group) and the closeness of social networks. Little research into the effect of these characteristics on travel patterns has been carried out to date.

10.6 THE INFLUENCE OF LAND USE CHARACTERISTICS ON TRAVEL PATTERNS

Analysis of national and local travel data has shown that land use characteristics are also associated with travel distance per person but not as strongly as socio-economic characteristics. The more important land use characteristics that are associated with travel distance include settlement size, job ratio, local facilities, population density and public transport frequency. Other land use characteristics that may also be linked to travel distance include the proximity to a railway station, the proximity to a motorway and the availability of residential parking. The research also suggests that public transport frequency and the proximity to a railway station may also be linked with car ownership which in turn may be linked to travel distance. Thus, land use characteristics are likely to have both a direct and an indirect effect on travel patterns: by affecting the distance between destinations and by affecting car ownership which then affects travel distance and mode.

Many of the land use characteristics associated with less travel are already included in planning policy guidance although most are expressed only as principles and there is little quantification or elaboration of criteria on which to base planning decisions.

The research has provided evidence to support all but one of the original seven secondary research hypotheses. There is however no evidence to support the hypothesis that average travel distance increases as the distance to the urban centre increases, whereas related characteristics such as settlement size and the provision of local facilities appear to be associated with travel distance (see below).

The results of the study support the hypothesis that travel distance per person decreases as settlement size increases. Results from the analysis of National Travel Survey data suggest that his may not be a simple linear relationship however. There appears to be a critical settlement size which is associated with lower travel distance per person. Average travel distance is consistently lower in London and other large urban areas containing more than 250,000 residents.

The results support the third hypothesis that average travel distance per person decreases as the proximity to local facilities increases. Analyses of National Travel Survey data indicate that average travel distance is shorter in areas close to local facilities (defined in terms of the nearest post office, chemist and grocers). There is also evidence to support the hypothesis that average travel distance per person decreases as the density of development increases. This applies only to ward-level population density however.

There is evidence to support the hypothesis that travel distance per person decreases as population density increases. Two measures of population density were examined: one at the ward level and the other at the local authority level. Only the measure of population density at the *ward level* appeared to be linked with travel distance. The results from both national and local data point to higher travel distances per person in low-density areas (less than 10 persons per hectare). Evidence from the National Travel Survey and the two local surveys (Kent and Leicestershire) indicate that travel distance is lowest in wards where the population density is between 40 and 50 persons per hectare. Travel distance per person is not as low in areas with densities of 50 persons per hectare.

Evidence from the analysis of travel data from Kent and Leicestershire support the hypothesis that average travel distance per person is lower where land uses are more mixed. Travel distance is lower in areas where the ratio of jobs to workers is high. Analysis of the Kent travel data supports the hypothesis that average travel distance per person is lower where residential parking is limited.

There is some evidence (although only partial) to support the hypothesis that average travel distance per person increases as the proximity to the main transport network (road and rail) increases. There is no evidence of a link between travel distance and the proximity to a bus stop but there is evidence of a link between the frequency of the local bus service and travel distance per person. There is also evidence of a link between the frequency of the local bus service and household car ownership. Evidence from Leicestershire indicates that travel distance may be higher in areas close to a railway station (but not in Kent). The results of the analysis of National Travel Survey data indicate a link between the proximity to a railway station and household car ownership: car ownership is lower near railway stations. The proximity to a railway station may therefore indirectly reduce travel distance by reducing car ownership since household car ownership is a strong determinant of travel distance per person. The link between travel distance and the proximity to the motorway network is unclear. The results of the analysis of travel data from Kent and Leicestershire are in opposition. Evidence from Kent indicates that travel distance is lower in areas adjacent to the motorway network whereas evidence from Leicestershire suggests that travel distance is higher in areas adjacent to the motorway network (which is the relationship in the hypothesis).

The study provides evidence to suggest that some land use characteristics may also have an influence on car ownership and indirectly affect travel distance (since car ownership is an important determinant of travel distance). The proximity to the nearest railway station and the frequency of public transport appear to be two important land use influences on car ownership.

In addition to the land use characteristics that were examined in this study, interviews with transport and land use professionals helped to identify several other land use characteristics that may influence travel distance. These include characteristics such as access to employment centres outside the city and the proximity of large local employers or large employment centres.

10.7 THE IMPLICATIONS FOR LAND USE PLANNING

Putting together all the land use characteristics associated with less travel would suggest that the most sustainable urban form from a travel reduction perspective is one composed of large, high-density, mixed-use settlements containing a range of local facilities with frequent, convenient public transport services. Clearly however all the land use characteristics identified as important for travel patterns sometimes cannot be combined. This is dependent on the type of area in which development takes place.

Research by Breheny et al (1995) suggests that local authorities attach high importance to some of the characteristics associated with less travel identified in this study (such as public transport provision and more intensive uses at nodes/corridors) and significantly less importance to other characteristics (such as housing density). Progress by local authorities in developing and implementing policies on each of these characteristics is variable. Many planning authorities now have policies to promote urban housing for example but fewer have policies on development density (Table 10.1). Raising the priority and importance of some land use policies (such as housing density) in the planning process is therefore necessary if certain land use characteristics are to be encouraged.

Some of the land use characteristics associated with less travel identified in this study may be complementary with others. On the other hand, some may be in conflict with others or may be in conflict with other goals of sustainability. Achieving the land use characteristics associated with less travel may have impacts on other issues of sustainable development such as regional development, urban green-space and quality of life. Strategic environmental assessment of plans and policies may help to avoid potential conflicts and identify how synergies might be maximised.

TABLE 10.1 PROGRESS AND IMPORTANCE OF SELECTED TRANSPORT AND LAND USE POLICIES IN ENGLAND

Progress [1] → *Importance* [2] ↓	*High*	*Medium*	*Low*
High	Urban housing	Public transport provision More intensive uses at nodes/corridors	
Medium		Mixed-use development Local facilities Parking standards On street parking	Housing density

Source: Breheny et al (1995).

The study has identified a variety of measures that can be used to support and enhance the effect of land use planning policies. Examples of measures that might be used to complement the effect of more sustainable land use planning policies include parking charges and restrictions, vehicle and fuel taxes, road and congestion charging, the reduction of road-space, public transport priority measures, restrictions in car access, greenfield land tax and derelict land grants.

1. Categories of *progress* are:
   - high = more than 66 per cent of authorities which have developed policies
   - medium = between 33 and 66 per cent of authorities which have developed policies
   - low = fewer than 33per cent of authorities which have developed policies
2. Categories of *importance* are:
   - high = more than 66 per cent of authorities regarding the issue as important
   - medium = between 33 and 66 per cent of authorities regarding the issue as important

The study has shown that most of the complementary measures are likely to influence a number of characteristics and not just a single land use characteristic. Some of the measures may promote certain land use characteristics but make others more difficult to achieve. Road and congestion charging for example might promote more self-contained settlements, more local facilities and the mixing of land uses but may on the other hand add to development pressures in areas where congestion is most severe and encourage development outside the areas affected by road or congestion charging and result in increased urban sprawl. Road or congestion charging may also act as a disincentive for some people to live or work in urban areas and increase the demand for smaller rather than larger settlements.

The study has shown that complementary measures to promote the role of land use planning policies need to be carefully selected to avoid possible conflicts with other land use characteristics. The introduction of policy packages rather than single measures may increase the influence of land use planning on travel patterns. There is a need to integrate as many of the land use characteristics into new development if it is to be more sustainable. High quality design is crucial to this integration if development is also to be attractive and durable.

The study has shown that although land use planning is just one of a number of measures that might influence travel, its contribution to reducing the need to travel is nevertheless important. Even though other measures may have more immediate or far-reaching effects, land use planning offers some advantages. Land use planning is more politically acceptable than several of the other measures that also might be used to reduce transport demand. Economic measures such as road pricing or fuel taxes might reduce transport demand equally well but introduction of such measures is very slow and cautious. Road pricing for example may be a more appropriate single measure to affect travel patterns but there are substantial political and operational problems with its implementation. In a review of various policy measures, Acutt and Dodgson (1996) show that land use planning is one of only a few measures that might both reduce travel and also contribute to a more equitable arrangement of land uses (Table 10.2). Another advantage of land use planning over many other measures is its potential to address the causes of transport problems rather than the symptoms. Land use planning offers the potential to reduce the need to travel by bringing activities closer together and increasing local convenience, whereas many other measures attempt to reduce transport demand by increasing the cost of movement or reducing the ease of movement.

Certain land use characteristics associated with less travel in this study may contribute to other goals of sustainable development. For example higher density development and lower parking provision reduce the amount of land and resources needed for development[1] (see for example Collie, 1990 or Stone, 1973). The development of large, high-density, mixed-use settlements containing a range of local facilities with frequent, convenient public transport services may also contribute to urban quality of life and regeneration.

TABLE 10.2 IMPACTS OF POLICY MEASURES ON TRAVEL DISTANCE (BY CAR) AND EQUITY ISSUES

Policy	*Travel distance by car*	*Equity issues*
1. Fuel taxes	Reduce total	Problems in rural areas
2. Variable car excise taxes	No direct impact	Improvements
3. Scrappage bounties	Small reduction	Improvements
4. Road congestion pricing	Reduction in priced area, but may increase elsewhere	Ambiguous
5. Vehicle use restrictions	Reduction	Ambiguous
6. Parking charges	Reduction in priced area, but ambiguous in total	Ambiguous
7. Parking controls	Reduction in controlled area, but may increase elsewhere	Ambiguous
8. Land use planning	Reduction if policy successful	Possible long term improvement
9. Traffic calming	Reduction in residential areas	Improvements possible
10. Public transport subsidies	Reduce total, especially urban	Improvements
11. Road construction	Increase	Could be negative

Source: Acutt and Dodgson (1996).

There are of course limitations to the role of land use planning however. According to Pickvance (1982 p.70), planning powers are essentially powers to prevent rather than powers to initiate. Planning is a policy measure that is reliant on a number of other agencies. It is for example reliant on developers and financiers to provide new development who work to different objectives which are not always coincident. There is therefore the need for negotiation between planners and developers, which does not always result in satisfying all objectives. Thus the extent to which land use planning can achieve more sustainable outcomes is dependent on issues such as the skill of negotiation, the bargaining position of the different parties and the ability to identify win-win situations. The reliance on developers and

1. Development costs may also be cheaper for higher density development with less parking.

financiers to provide development means that the strength of land use planning measures are dependent on the state of the national and/or the local economy. In practice, development plans and policies may be influenced more by market forces than other considerations such as sustainability (see for example Pickvance, 1982).

There are also a number of problems and barriers to the introduction of many of the land use planning characteristics into decision-making. Certain land use characteristics associated with less travel in this study do not have widespread political or public support. Higher densities and larger settlement sizes run counter to current demographic trends although it may be quality of life issues, rather than the land use characteristics of these areas, that people are choosing to move away from. Higher densities are also potentially in conflict with other objectives of sustainable development such as access to open space and urban biodiversity. The development of large, high-density, mixed-use settlements containing a range of local facilities with frequent, convenient public transport services may contribute positively to urban quality of life but may do little for rural development. Overcoming the problems and barriers to the introduction of more sustainable land use policies requires concerted action using a combination of economic and regulatory levers, training and education and awareness campaigns. The issue of barriers and obstacles to the introduction of more sustainable land use policies is an area where little research has been conducted and needs to be investigated further. More work needs to be done to identify the components of successful strategies if barriers and obstacles to the introduction of certain policies are to be overcome. Some of the strong driving forces that have led to less sustainable trends in land use (such as the spiral of increasing car ownership leading to more expensive and less frequent public transport) require strong action to reverse them. Other complementary measures including land use planning policies must be used in combination with economic measures to move from a vicious circle of transport and land use policies to a virtuous circle of measures. Bringing together mutually reinforcing land and complementary policies provides a powerful virtuous circle of measures that may contribute to economic, social and environmental benefits.

One of the main messages from this research is that more sustainable land use patterns require the integration of a number of land use characteristics together with good public transport accessibility. The effectiveness of land use planning is likely to be further assisted by the introduction of a variety of complementary measures, some of which are outside the influence of land use planning. Coordinated action is required at a number of different levels of decision-making to introduce more sustainable planning policies.

10.8 Recommendations for Further Research

Residual analysis ('hotspot' and 'coldspot' analysis) in conjunction with interviews has proved to be a useful method for identifying additional socio-economic and land use characteristics that might underlie the results of the study. The socio-economic characteristics identified in this study that explain some of the variation in travel patterns has provided a more sophisticated framework than used in other previous research for exploring the reasons for travel patterns in different locations. Longitudinal studies may have helped to examine some of the cause and effect relationships between land use and travel in more detail. Additional research into the socio-economic and land use issues identified from the residual analysis may also have been a productive way of identifying other reasons for the variation of travel in different locations. These are potential areas for further research.

The study has not included qualitative or more complex composite measures of land use characteristics such as quality of life or 'liveability' because although important there is no agreed way of identifying them (see section 10.4). These 'softer' measures are likely to influence the socio-economic profile of an area and possibly local travel patterns. Future studies might try to examine the potential links between these more qualitative characteristics, travel patterns and socio-economic characteristics by devising some synthetic measures of land use and urban form. 'Hotspot' and 'coldspot' analysis might be used as a starting point for the identification of such measures.

Further research into the planning implications for travel 'hotspots' and 'coldspots' are still required. What need to be established are answers to questions such as:

- should new development be located in areas where there is less travel?
- would new development in such areas affect travel patterns for the worse (if for example new homes were built which relied on existing infrastructure, services and facilities)?
- is there a case for locating new development in areas that are currently associated with more travel if new development could bring about changes in the urban form and reduce travel?

Closely related to these issues are questions of acceptability such as:

- how can visions of new 'liveable' urban forms be developed?
- how might these visions be used to identify plans and policies?
- is it possible to improve the desirability of different urban forms through design?

The question of acceptability to different groups is also important:

- are there particular groups of individuals or professions that it is necessary to influence if new urban forms are to become more desirable?
- what are current location and design preferences (both in terms of the public and developers)?

Finally, further research needs to identify some of the knock-on effects of policies to promote more sustainable urban form in terms of other land use issues such as land and property prices, migration and employment relocation. The complex issue of obstacles and barriers to the implementation of land use policies is another area where further investigation might uncover how more sustainable policies can be implemented more effectively.

BIBLIOGRAPHY

Acutt, M. and Dodgson, J. (1996) Policy Instruments and Greenhouse Gas Emissions from Transport in the UK. *Fiscal Studies*, Vol.17, No.2, pp. 65-82.

Anable, J.; Boardman, B. and Root, A. (1997). *Travel Emission Profiles: A Tool for Strategy Development and Driver Advice.* Environmental Change Unit, University of Oxford, Oxford.

Appleyard, D. and Lintell, M. (1969). The Environmental Quality of City Streets: The Resident Perspective. *Journal of the American Planning Association.* Vol.35, pp. 84-101.

Balcombe, R.J. and York, I.O. (1993). *The Future of Residential Parking.* Transport Research Laboratory Report, Crowthorne.

Banister, D. (1996). Energy, Quality of Life and the Environment: The Role of Transport. *Transport Reviews.* Vol.16, No.1, pp.23-35.

Banister, D. (1997). Reducing the Need to Travel. *Environment and Planning B: Planning and Design*, Vol.24, No.1, pp.125-143.

Banister, D. (1998a). Introduction: Transport Policy and the Environment. In: Banister, D. (ed.) *Transport Policy and the Environment.* E. and F.N. Spon, London. pp. 1-16.

Banister, D. (1998b). Barriers to the Implementation of Urban Sustainability. *International Journal of Environment and Pollution*, Vol.10, No.1, pp.65-83.

Banister, D. and Banister, C. (1995). Energy Consumption in Transport in Great Britain: Macro Level Estimates. *Transportation Research A.* Vol.29A, No.1, pp.21-32.

Banister, D.; Watson, S. and Wood C. (1997). Sustainable Cities, Transport, Energy, and Urban Form. *Environment and Planning B: Planning and Design.* Vol.24, pp.125-143.

Barde, J-P. and Button, K. (1990). Introduction. In: Barde, J-P. and Button, K. (eds.). *Transport Policy and the Environment. Six case Studies.* Earthscan, London. pp. 1-18.

Barton, H.; Davies, G. and Guise, R, (1995). *Sustainable Settlements – A Guide for Planners, Designers and Developers.* Local Government Management Board, Luton.

Breheny M. (1992a). Towards Sustainable Urban Development. In: Mannion, A.M. and Bowlby, S.R. (eds.) *Environmental Issues in the 1990s*. John Wiley and Sons Ltd., London. pp. 277-290.

Breheny, M. (1992b). The Contradictions of the Compact City: A Review. In: Breheny, M. (ed.). *Sustainable Development and Urban Form.* Pion, London. pp.138-159.

Breheny, M. (1995). Counterurbanisation and Sustainable Urban Forms. In: Brotchie, J.; Batty, M.; Blakely, E.; Hall, P. and Newton, P. (eds.) *Cities in Competition. Productive and Sustainable Cities for the 21st Century.* Longman Australia Pty. Ltd., Melbourne. pp.402-429.

Breheny, M. and Archer, S. (1998). Urban Densities, Local Policies and Sustainable Development. *International Journal of Environment and Pollution*, Vol.10, No.1, pp.126-150.

Breheny, M. and Rockwood, R. (1993). Planning the Sustainable City Region. In: Blowers, A. (ed.) *Planning for a Sustainable Environment.* Earthscan, London. pp.150-189.

Breheny, M.; Gurney, A. and Strike, J. (1995). The Compact City and the Need to Travel: The Implementation of UK Planning Policy Guidance. In: Jenks, M.; Burton, E. and Williams, K. (eds.). *The Compact City. A Sustainable Urban Form?* E. and F.N. Spon, London, pp.302-317.

Cadman, D. and Topping, R. (1995). *Property Development.* E and F.N. Spon, London.

Central Statistical Office (1997). *Annual Abstract of Statistics.* The Stationery Office, London.

Cervero, R. (1989). Jobs-Housing Balancing and Regional Mobility. *Journal of the American Planning Association.* Vol.55, No.2, pp.136-150.

Cervero, R. (1994). Transit-Based Housing in California: Evidence on Ridership Impacts. *Transport Policy.* Vol.1, No.3, pp.174-183.

Cervero, R. (1996). Jobs-Housing Balancing Revisited. *Journal of the American Planning Association.* Vol.62, No.4, pp.492-511.

Cervero, R. and Landis, J. (1992). Suburbanisation of Jobs and the Journey to Work: a Submarket Analysis of Commuting in the San Francisco Bay Area. *Journal of Advanced Transportation.* Vol.26, No.3, pp.275-297.

Champion, T.; Atkins, D.; Coombes, M. and Fotheringham, S. (1998). *Urban Exodus.* CPRE, London.

Collie, M. (1990). The case for Urban Consolidation. *Australian Planner.* Vol.28, No.2, pp.26-33.

Commission of the European Communities (1992). *The Impact of Transport on the Environment.* Office for Official Publications of the European Communities, Luxembourg.

Commission of the European Communities (1995). *Fifth Environmental Action Plan.* Office for Official Publications of the European Communities, Luxembourg.

Commission of the European Communities (1998). *Communication from the Commission on Transport and CO_2 – Developing a Community Approach.* Office for Official Publications of the European Communities, Luxembourg.

Committee on the Medical Effects of Air Pollutants (1998). *The Quantification of the Effects of Air Pollution on Health in the United Kingdom.* The Stationery Office, London.

Curtis, C. (1995). Reducing the Need to Travel: Strategic Housing Location and Travel Behaviour. In: Earp, J.H.; Headicar, P.; Banister, D. and Curtis, C. *Reducing the Need to Travel: Some Thoughts on PPG13. Oxford Planning Monographs.* Vol.1, No.2, pp.29-47.

Damm, D. (1981). Theory and Empirical Results: A Comparison of Recent Activity-based Research. In: Jones, P. and Carpenter, S. (eds.). *Recent Advances in Travel Demand Analysis.* Gower, Aldershot. pp.3-33.

Department of the Environment (1992a). *Planning Policy Guidance 4: Industrial and Commercial Development and Small Firms.* HMSO, London.

Department of the Environment (1992b). *Planning Policy Guidance 3: Housing.* HMSO, London.

Department of the Environment (1993). *Environmental Appraisal of Development Plans.* HMSO, London.

Department of the Environment (1994). *Planning Policy Guidance 13: Transport.* HMSO, London.

Department of the Environment (1995). *PPG13 A Guide to Better Practice. Reducing the Need to Travel through Land Use and Transport Planning.* HMSO, London.

Department of the Environment (1996a). *Indicators of Sustainable Development for the United Kingdom.* HMSO, London.

Department of the Environment (1996b). *Planning Policy Guidance 6: Town Centres and Retail Development.* The Stationery Office, London.

Department of the Environment (1997a). *United Kingdom National Air Quality Strategy.* The Stationery Office, London.

Department of the Environment (1997b). *Planning Policy Guidance 1: Planning Policy and Principles.* The Stationery Office, London.

Department of the Environment (1997c). *Planning Policy Guidance 7: The Countryside – Environmental Quality and Economic and Social Development.* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1997a). *Land Use Change in England No.12.* Department of the Environment, Transport and the Regions, London.

Department of the Environment, Transport and the Regions (1997b). *Transport Statistics Great Britain 1997.* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1997c). *Digest of Environmental Statistics 1997.* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1997d). *Air Quality and Traffic Management [LAQM. G3(97)].* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1997e). *National Travel Survey 1994/96.* HMSO, London.

Department of the Environment, Transport and the Regions (1997f). *Air Quality and Land Use Planning [LAQM. G4(97)].* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1997g). *Guidance for Transport Policies and Programme Submissions for 1999-00.* Department of the Environment, Transport and the Regions, London.

Department of the Environment, Transport and the Regions (1997h). *Environment Circular 15/97. Part IV The Environment Act 1995 Local Air Quality Management.* Department of the Environment, Transport and the Regions, London.

Department of the Environment, Transport and the Regions (1998a). *A New Deal for Trunk Roads in England.* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1998b). *John Prescott Announces Urban White Paper. Press Release 871 (20/10/98).* Department of the Environment, Transport and the Regions, London.

Department of the Environment, Transport and the Regions (1998c). *A New Deal for Transport: Better for Everyone.* The Stationery Office, London.

Department of the Environment, Transport and the Regions (1998d). *The Future of Regional Planning Guidance. Consultation Paper.* Department of the Environment, Transport and the Regions, London.

Department of the Environment, Transport and the Regions (1998e). *Sustainability Counts.* Department of the Environment, Transport and the Regions, London.

Department of Trade and Industry (1995). *Energy Projections for the UK. Energy Paper 65.* HMSO, London.

Department of Trade and Industry (1997). *Digest of UK Energy Statistics.* The Stationery Office, London.

Department of Transport (1986). *Transport Statistics Great Britain 1975-85.* HMSO, London.

Department of Transport (1987). *Transport Statistics Great Britain 1976-86.* HMSO, London.

Department of Transport (1990). *Transport Statistics Great Britain 1979-89.* HMSO, London.

Department of Transport (1991). *Transport Statistics Great Britain 1980-1990.* HMSO, London.

Department of Transport (1992a). *National Travel Survey 1978/79 [computer file].* ESRC Data Archive, Colchester.

Department of Transport (1992b). *National Travel Survey 1985/86 [computer file].* ESRC Data Archive, Colchester.

Department of Transport (1992c). *Transport Statistics Great Britain 1981-1991.* HMSO, London.

Department of Transport (1993). *Transport Statistics Great Britain 1993.* HMSO, London.

Department of Transport (1994a). *National Travel Survey 1991/93.* HMSO, London.

Department of Transport (1994b). *Transport Statistics Great Britain 1994.* HMSO, London.

Department of Transport (1995a). *National Travel Survey 1992/94.* HMSO, London.

Department of Transport (1995b). *National Travel Survey 1988/93 [computer file].* ESRC Data Archive, Colchester.

Department of Transport (1995c). *Tabulations from National Travel Surveys supplied to the author.*

Department of Transport (1995d). *Transport Statistics Great Britain 1995.* HMSO, London.

Department of Transport (1996a). *Transport Statistics Great Britain 1996.* HMSO, London.

Department of Transport (1996b). *National Travel Survey 1993/95.* HMSO, London.

Ebdon, D. (1985). *Statistics in Geography. Second Edition.* Basil Blackwell, London.

ECOTEC (1993). *Reducing Transport Emissions Through Planning.* HMSO, London.

Eggleston, H. (1992) *Pollution in the Atmosphere: Future Emissions from the UK.* Report LR888 (AP), Warren Spring Laboratories, Stevenage.

Elkin, T.; McLaren, D. and Hillman, M. (1991). *Reviving the City. Towards Sustainable Urban Development.* Friends of the Earth/Policy Studies Institute, London.

Ewing, R. (1995). Beyond Density, Mode Choice, and Single Trips. *Transportation Quarterly.* Vol.49, No.4, pp.15-24.

Ewing. R; DeAnna, M. and Li, S-C. (1996). Land Use Impacts on Trip Generation Rates. *Transportation Research Record.* Vol.1518, pp.1-6.

Farthing, S.; Winter, J. and Coombes, T. (1997). Travel Behaviour and Local Accessibility to Services and Facilities. In: Jenks, M.; Burton, E. and Williams, K. (eds.) *The Compact City. A Sustainable Urban Form?* E. and F.N. Spon, London. pp.181-189.

Fielding, T. and Halford, S. (1990). *Patterns and Processes of Urban Change in the United Kingdom: Reviews of Urban Research.* HMSO, London.

Flannelly, K.J. and McLeod, M.S (1989). A Multivariate Analysis of Socioeconomic and Attitudinal Factors Predicting Commuters' Mode of Travel. *Bulletin of the Psychonomic Society.* Vol.27, No.1, pp.64-66.

Frank, L.& Pivo, G. (1994). Impacts of Mixed Use and Density on Utilization of three Modes of Travel: Single-occupant Vehicle, Transit, and Walking. *Transportation Research Record.* Vol.1466, pp.44-52.

Giuliano, G. and Small, K. (1993). Is the Journey to Work explained by Urban Structure? *Urban Studies.* Vol.30, No.9. pp.1485-1500.

Goodwin, P. (ed.) (1995). *Car Dependence.* RAC Foundation for Motoring and the Environment, London.

Goodwin, P.; Hallet, S.; Kenny, F. and Stokes, G. (1991). *Transport: the New Realism. Report 624.* Transport Studies Unit, University of Oxford.

Gordon, I. (1997). Densities, Urban Form and Travel Behaviour. *Town and Country Planning.* Vol.66, No.9, pp.239-241.

Gordon, P.; Kumar, A. and Richardson, H.W. (1989a). Congestion, Changing Metropolitan Structure and City Size in the United States. *International Regional Science Review.* Vol.12, No.1, pp.45-56.

Gordon, P.; Kumar, A. and Richardson, H.W. (1989b). Gender Differences in Metropolitan Travel Behaviour. *Regional Studies.* Vol.23, No.6, pp.499-510.

Gordon, P.; Richardson, H.W. and Jun, M-J. (1991). The Commuting Paradox: Evidence from the Top Twenty. *Journal of the American Planning Association.* Vol.57, No.4, pp.416-420.

Gorham, R. (1998). *Land-Use Planning and Sustainable Urban Travel. Overcoming Barriers to Effective Co-ordination.* Background Document to the OECD-ECMT Workshop on Land-Use for Sustainable Transport: Implementing Change, September, Linz.

Gover, M.P.; Hitchcock, G.S.; Collings, S.A. and Moon, D.P. (1994). *UK Petrol and Diesel Demand. Energy and Emissions Effects of a Switch to Diesel.* HMSO, London.

Hair, J.F.; Anderson, R.E.; Tatham, R.L. and Black, W.C. (1995). *Multivariate Data Analysis with Readings. Fourth Edition.* Prentice-Hall Inc., Englewood Cliffs (NJ).

Handy, S. (1992). Regional versus Local Accessibility. Neotraditional Development and its Implications for Non-work Travel. *Built Environment.* Vol.18, No.4, pp.253-267.

Hanson, S. (1982). The Determinants of Daily Travel-activity Patterns: Relative Location and Sociodemographic Factors. *Urban Geography.* Vol.3, No.3, pp.179-202.

Haq, G. (1997). *Towards Sustainable Transport Planning.* Avebury, Aldershot.

Hardy, M.A. (1993). Regression Analysis with Dummy Variables. In: Lewis-Beck, M.S. (ed.) *Regression Analysis.* Sage Publications, London, pp.69-158.

Haughton, G. and Hunter, C. (1994). *Sustainable Cities.* Jessica Kingsley, London.

Headicar, P. and Curtis, C. (1994). Residential Development and Car-Based Travel: Does Location Make a Difference? *Proceedings of Seminar C – Environmental Issues, 22nd PTRC European Transport Forum*, Warwick, September. pp.117-130.

Hillman M. and Whalley, A. (1983). *Energy and Personal Travel: Obstacles to Conservation.* Policy Studies Institute, London.

Hillman M.; Henderson, I. and Whalley, A. (1973). *Personal Mobility and Transport Policy.* Policy Studies Institute, London.

Hillman M.; Henderson, I. and Whalley, A. (1976). *Transport Realities and Planning Policy: Studies of Friction and Freedom in Daily Travel.* Policy Studies Institute, London.

HM Government (1994). *Sustainable Development. The UK Strategy.* HMSO, London.

HM Government (1996). *Household Growth: Where Shall We Live?* The Stationery Office, London.

HM Treasury (1998). *Tax Measures to Help Protect the Environment. Press Release 13 (17/03/98)*, HM Treasury, London.

Howard, D. (1990). Looking Beyond the Technical Fix. *Town and Country Planning.* Vol.59, No.12, pp.343-345.

Hughes, P. (1992). The Role of Passenger Transport in CO_2 Reduction Strategies. *Energy Policy.* Vol.20, No.2, pp.149-160.

Hughes, P. (1993). *Personal Transport and the Greenhouse Effect.* Earthscan, London.

Johnston-Anumonwo, I. (1992). The Influence of Household Type on Gender Differences in Work Trip Distance. *Professional Geographer.* Vol.44, No.2, pp.161-169.

Jones, D.M. (1990). Noise, Stress and Human Behaviour. *Environmental Health.* Vol.98, No.8, pp.206-208.

Kitamura, R.; Mokhtarian, P. and Laidet, L. (1997). A Micro-analysis of Land Use and Travel in five Neighbourhoods in the San Francisco Bay Area. *Transportation.* Vol.24, pp.125-158.

Lainton, A. (1996). Drawing up the Right Recipe for Appetising Land Use Mix. *Planning.* Vol.1184, p.21.

Leicestershire County Council (1994). *Leicestershire Structure Plan.* Leicestershire County Council, Leicester.

Levinson, D.M. and Kumar, A. (1997). Density and the Journey to Work. *Growth and Change.* Vol.28, pp.147-172.

Llewelyn-Davies (1998). *The Use of Density in Land Use Planning. Report for the Department of the Environment, Transport and the Regions.* Llewelyn-Davies, London.

Local Government Management Board (1994). *Sustainability Indicators Research Project. Report of Phase One.* Local Government Management Board, Luton.

Maddison, D.; Pearce, D.; Johansson, O.; Calthrop, E.; Litman, T. and Verhoef, E. (1995). *Blueprint 5. The True Costs of Road Transport.* Earthscan, London.

Maritime and Coastguard Agency (1997). *The Sea Empress Incident: Summary Report.* Maritime and Coastguard Agency, Southampton.

Martin, D. and Shock, R. (1989). *Energy Use and Energy Efficiency in UK Transport up to the Year 2010.* HMSO, London.

McDougall, G.H.G. and Mank, R.B. (1982). Consumer Energy Conservation Policy in Canada. Behavioural and Institutional Obstacles. *Energy Policy.* Vol.10, No.3, pp.212-224.

Mill, J.S. (1854). *A System of Logic, Ratiocinative and Inductive: Being a Connected View of the Principles of Evidence and Methods of Scientific Investigation.* J.W. Parker, London.

Mogridge, M.J.H. (1985). Transport, Land Use and Energy Interaction. *Urban Studies.* Vol.22, pp.481-492.

Næss, P. (1993). Transportation Energy in Swedish Towns and Regions. *Scandinavian Housing and Planning Research.* Vol.10, pp.187-206.

Næss, P. and Sandberg, S.L. (1996). Workplace Location, Modal Split and Energy Use for Commuting Trips. *Urban Studies.* Vol.33, No.3, pp.557-580.

Næss, P.; Røe, P.G. and Larsen, S. (1995). Travelling Distances, Modal Split and Transportation Energy in thirty Residential Areas in Oslo. *Journal of Environmental Planning and Management.* Vol.38, No.3, pp.349-370.

Needham, B.; Koenders, K. and Kruijt, B. (1993). *Urban Land and Property Markets in the Netherlands.* UCL Press, London.

Newby, H. (1990). Revitalizing the Countryside: The Opportunities and Pitfalls of Counter-urban Trends. *Journal of the Royal Society of the Arts.* Vol.138, pp.630-636.

Newman, P.W.G. and Kenworthy, J.R. (1988). The Transport Energy Trade-off: Fuel Efficient Traffic versus Fuel-efficient Cities. *Transportation Research.* Vol.22A, No.3, pp.163-174.

Newman, P.W.G. and Kenworthy, J.R. (1989). *Cities and Automobile Dependence. An International Sourcebook.* Gower Technical, Aldershot.

Newman, P.W.G.; Kenworthy, J.R. and Lyons, T.J. (1985). Transport Energy Use in the Perth Metropolitan Region: Some Urban Policy Implications. *Urban Policy and Research.* Vol.3, No.2, pp.4-15.

Newton, P.N. (ed.) (1997). *Reshaping Cities for a More Sustainable Future – Exploring the Link between Urban Form, Air Quality, Energy and Greenhouse Gas Emissions. Research Monograph 6.* Australian Housing and Research Institute, Melbourne.

OECD (1988). *Transport and the Environment.* OECD, Paris.

OECD (1991). *The State of the Environment.* OECD, Paris.

Office for Population Censuses and Surveys (1995). *1991 Census General Report.* HMSO, London.

Owens, S. (1986). *Energy Planning and Urban Form.* Pion, London.

Pharoah, T. (1992). *Less Traffic Better Towns.* Friends of the Earth, London.

Pickvance, C. (1982). Physical Planning and Market Forces in Urban Development. In: Paris, C. (ed.) *Critical Readings in Planning Theory.* Pergamon, Oxford pp.69-82.

Post Office (1995). *Postzon File [computer file] documentation.* ESRC Data Archive, Colchester, Essex.

Potter, S. (1997). *Vital Travel Statistics.* Landor Publishing, London.

Prevedouros, P.D. (1992). Associations of Personality Characteristics with Transport Behavior and Residence Location Decisions. *Transportation Research A.* Vol.26, No.5, pp.381-391.

Prevedouros, P.D. and Schofer, J. (1991). Trip characteristics and travel patterns of suburban residents. *Transportation Research Record.* Vol.1328, pp.49-57.

Redsell, M. Lucas, G. and Ashford, N. (1988). *Comparison of On-Road Fuel Consumption for Diesel and Petrol Cars.* Transport and Road Research Laboratory Contractor Report 79. TRRL, Crowthorne.

Roberts, I.G. (1993). International Trends in Pedestrian Injury Mortality. *Archives of Disease in Childhood.* Vol.68, pp.190-192.

Royal Commission on Environmental Pollution (1994). *Eighteenth Report. Transport and the Environment.* HMSO, London.

Royal Commission on Environmental Pollution (1997). *Twentieth Report. Transport and the Environment – Developments since 1994.* The Stationery Office, London.

Royal Town Planning Institute (1991). *Traffic Growth and Planning Policy.* Royal Town Planning Institute, London.

Shaw, G. and Wheeler, D. (1994). *Statistical Techniques in Geographical Analysis. Second Edition.* David Foulton Publishers, London.

Sorrell, S. (1992). Fuel Efficiency in the UK Vehicle Stock. *Energy Policy.* Vol.19, No.5, pp.766-780.

Spence, N. and Frost, M. (1995) Work Travel Responses to Changing Workplaces and Changing Residences. In: Brotchie, J.; Batty, M.; Blakely, E.; Hall, P. and Newton, P. (eds.) *Cities in Competition. Productive and Sustainable Cities for the 21st Century.* Longman Australia Pty. Ltd., Melbourne. pp.359-381.

Standing Advisory Committee on Trunk Road Appraisal (SACTRA) (1994). *Trunk Roads and the Generation of Traffic. Report of the Standing Advisory Committee on Trunk Road Appraisal.* HMSO, London.

Stead, D. and Davis, A. (1998). Increasing the Need to Travel? Parental Choice and Travel to School. *Proceedings of Seminar C – Policy, Planning and Sustainability, 26th PTRC European Transport Forum*, Loughborough, September. pp.75-88.

Stone, P.A. (1973). *The Structure, Size and costs of Urban Settlements.* Cambridge University Press, Cambridge.

Taylor, S.M. and Watkins, P.A. (1987). *Health Effects from Transportation Noise Reference Book.* Butterworth, London.

The Housebuilders Federation (1997). *New Homes Because Britain Deserves Better. An Agenda for the New Government.* The Housebuilders Federation, London.

Thérivel, R. (1998). Strategic Environmental Assessment in the Transport Sector. In: Banister, D. (ed.) *Transport Policy and the Environment.* E. and F.N. Spon, London. pp.50-71.

Thérivel, R. and Partidário, M.R. (1996). *The Practice of Strategic Environmental Assessment.* Earthscan, London.

Thérivel, R.; Wilson, E.; Thompson, S.; Heaney, D. and Pritchard, D. (1992). *Strategic Environmental Assessment.* Earthscan, London.

Thomas, E.N. (1968). Maps of Residuals from Regression. In: Berry, B.J. and Marble, D.F. (eds.) *Spatial Analysis: A Reader in Statistical Geography.* Prentice-Hall Inc., Englewood Cliffs (NJ). pp.326-352.

Tomkins, R. and Wade, J. (1989). Transport Energy in Britain: Future Trends and Carbon Dioxide Emissions. *International Journal of Ambient Energy.* Vol.10, No.4, pp.171-193.

Troy, P.N. (1992). Let's Look at that Again. *Urban Policy and Research.* Vol.10, No.1, pp.41-49.

United Nations (1993). *Earth Summit. Agenda 21 The United Nations Programme of Action from Rio.* United Nations, New York.

Valleley, M., Jones, P., Wofinden, D. and Flack, S. (1997). The Role of Parking Standards in Sustainable Development. *Proceedings of Seminar C – Policy, Planning and Sustainability, 25th PTRC European Transport Forum*, Uxbridge, September. pp.393-411.

Webster, F.V.; Bly, P.H. and Paulley, N.J. (1988). *Urban Land-Use and Transport Interaction: Policies and Models.* Gower, Aldershot.

Wegener, M. (1994). Operational Urban Models: State of the Art. *Journal of the American Planning Association.* Vol.60, No.1, pp. 17-29.

Welsh Office (1997). *Planning Guidance (Wales) – Planning Policy.* The Stationery Office, London.

Welsh Office (1998). *Technical Advice Note (Wales) 18 – Transport.* The Stationery Office, London.

Wilson, A.G. (1998). Land-Use/Transport Interaction Models: Past and Future. *Journal of Transport Economics and Policy.* Vol.32, No.1, pp.3-27.

Winter, J. and Farthing, S. (1997). Coordinating Facility Provision and New Housing Development: Impacts on Car and Local Facility Use. In: Farthing, S.M. (ed.) *Evaluating Local Environmental Policy.* Avebury, Aldershot. pp. 159-179.

Woolley J.E. and Young, T.M. (1994). Environment: The Third Dimension of the Land Use Transport Interaction. *Papers of the Australasian Road Transport Research Forum*. Vol.19, pp.223-239.

APPENDICES

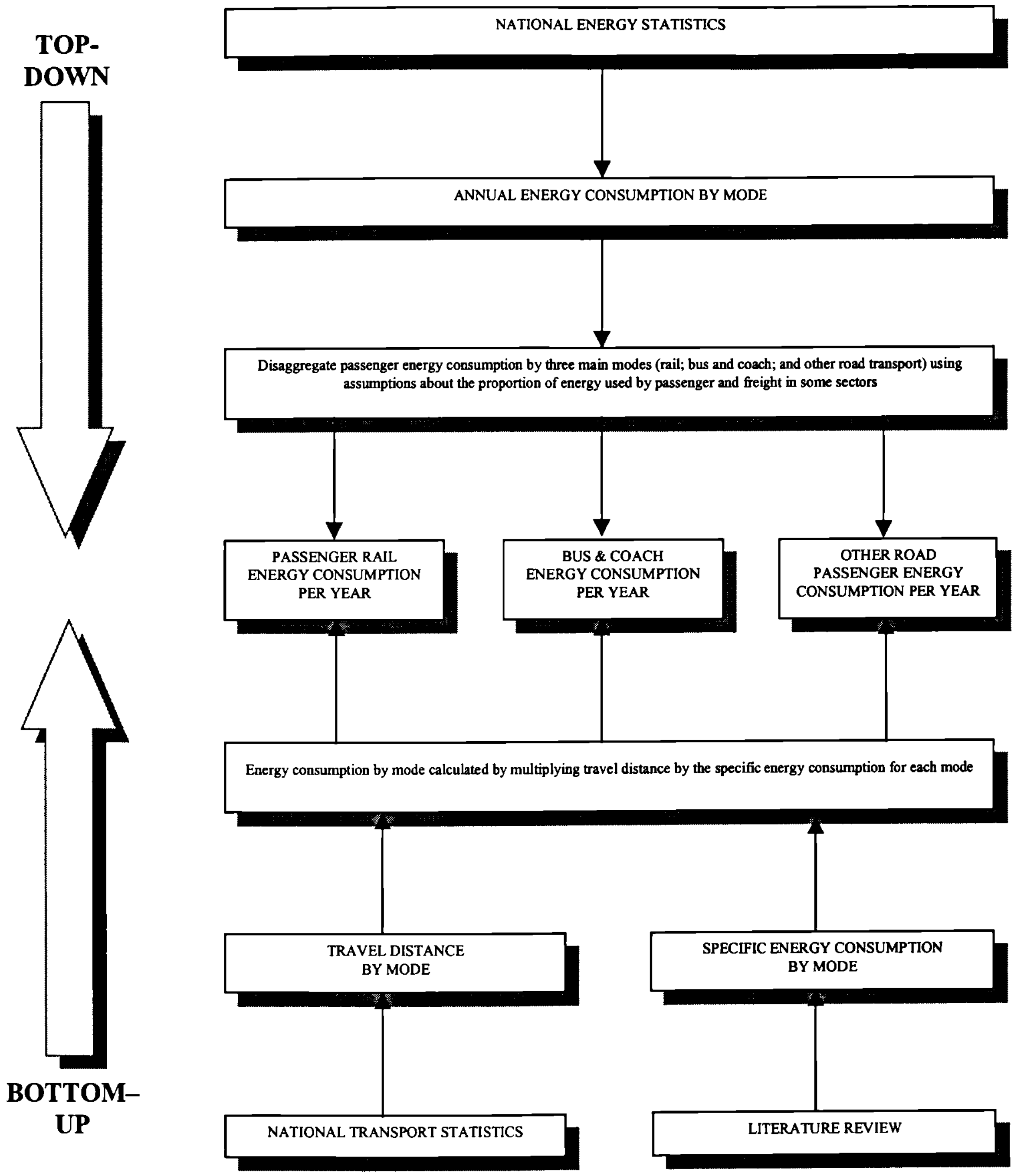
APPENDIX 1: TYPICAL VEHICLE ENERGY CONSUMPTION VALUES

This Appendix identifies typical energy consumption for different modes of transport. To do so, transport energy consumption is calculated using two approaches, one of which employs assumptions about the typical energy consumption of different modes of transport. The results of the two approaches are then reconciled in order to identify typical energy consumption figures that give consistent transport energy consumption figures for both approaches.

Banister and Banister (1995) identify two approaches for calculating transport energy consumption by mode. The starting point for the first, described as a *top-down approach*, is national energy statistics (Figure A1.1). National energy statistics are first disaggregated by sector and mode. The proportions of energy used for the movement of passengers and freight are then used to calculate passenger transport energy consumption by mode. The second approach, described as a *bottom-up approach*, involves the use of national travel statistics to establish passenger travel distance per person by mode (Figure A1.1). The specific energy consumption (SEC) of each mode is used to calculate passenger transport energy consumption per person by mode. Annual passenger transport energy consumption per person is then obtained by multiplying the above figure by the population of Great Britain. The two approaches are employed in Appendix 1 in order to establish SEC values which provide consistency of results between top-down and bottom-up approaches.

Energy and travel data for four periods were collected, coinciding with the dates of four National Travel Surveys (1985/86, 1989/91, 1991/93 and 1993/95). Inconsistent reporting of energy and transport statistics further back than 1985 prevented analysis across a longer time period. Table A1.1 presents the calculations of transport energy consumption by mode using the top-down approach. Assumptions about the proportion of energy used for the movement of passengers and freight in the rail sector were necessary in order to differentiate between the passenger and freight components of the energy consumption figure for rail. The range of energy consumption for rail shown in Table A1.1 reflects a high and low estimate of the proportion of energy used for the movement of passengers and freight in the sector. It has been assumed that between 80% and 99% of all energy consumed in the rail sector was used in the transport of passengers. Banister and Banister (1995) estimate that the movement of passengers by rail accounted for approximately 89% of all energy consumed in the rail sector[1].

FIGURE A1.1 THE TOP-DOWN AND BOTTOM-UP APPROACHES



1. Tables 10 and 12 in Banister and Banister (1995).

TABLE A1.1 PASSENGER TRANSPORT ENERGY CONSUMPTION BY MODE CALCULATED USING THE TOP-DOWN APPROACH

Mode	*Energy Consumption (PJ or 10^{15}J)* 1985/86	*1989/91*	*1991/93*	*1993/95*
Road excluding bus/coach	884	1071	1118	1128
Bus/coach	46	49	50	52
Rail	54-66	53-65	52-64	51-63
Total	984-996	1173-1185	1219-1231	1231-1243

Sources: Department of Transport (1986, 1987, 1990, 1991, 1992c, 1993, 1994b, 1995d, 1996a).

Estimates based on the top-down method indicate that 70-75% of energy supplied to the transport sector was consumed by passenger transport and 25-30% was consumed by freight transport. Passenger transport is therefore a substantially larger consumer of energy than freight transport. Road transport accounts for the largest share of passenger transport energy consumption. Road vehicles consume between 75% and 80% of all energy supplied to passenger transport.

The bottom-up approach involves the use of national travel statistics to establish passenger travel distance per person by mode. These are set out for 1985/86, 1989/91, 1991/93 and 1993/95 in Table A1.2. The table shows that car is by far the dominant mode of transport, accounting for 77% of all distance travelled in 1993/95 and 71% of all distance in 1985/86.

The range of specific energy consumption (SEC) figures quoted in recent literature is shown in Table A1.3. There are substantial differences between low and high SEC values for most modes, reflecting different assumptions about passenger occupancy and typical vehicle energy efficiency.

TABLE A1.2 PASSENGER TRAVEL DISTANCE PER PERSON BY MODE

Mode	*1985/86*	*1989/91*	*1991/93*	*1993/95*	*Percentage Change 1985/86-1993/95*
	Distance / person / year (miles)				
Car	3796	4809	4944	5008	+32%
Stage bus	297	275	263	258	-13%
Private hire bus	131	123	123	108	-18%
Express bus	109	123	105	95	-13%
British Rail	292	366	311	294	+1%
Underground	44	49	48	53	+20%
Van	228	301	264	288	+26%
Walk	244	237	212	200	-18%
Motorcycle	51	35	38	32	-37%
Bicycle	44	41	39	37	-16%
Taxi	27	42	40	39	+44%
Other private	33	34	41	38	+15%
Other public	22	40	46	62	+182%
Total	5317	6475	6473	6511	+22%

Sources Department of Transport (1994b and 1996b).

TABLE A1.3 THE RANGE OF SEC VALUES USED IN RECENT TRANSPORT ENERGY STUDIES

Source →	*Specific Energy Consumption (MJ/passenger-kilometre)*						
Mode ↓	*Banister et al, 1997*	*CEC, 1992*[1]	*Hillman & Whalley, 1983*[2]	*Hughes, 1992*	*Martin & Shock, 1990*	*Tomkins & Wade, 1989*[2]	*Summary*
	low high	*low high*	*low high*	*low high*	*low high*	*low high*	*low high*
Car	1.30 - 3.00	1.13 - 4.65	1.47 - 3.22	1.50 - 3.08	1.30 - 2.80	1.07 - 3.09	1.07 - 4.65
Stage bus	0.75 - 1.20	0.35 - 1.17	0.49 - 0.98	0.52 - 0.87	0.30 - 1.60	0.56 - 0.94	0.30 - 1.60
Express bus	0.98 - 0.98	0.50 - 0.95	0.32 - 0.32	0.38 - 0.38	0.50 - 1.00	0.16 - 0.16	0.16 - 1.00
Rail	1.10 - 2.30	0.57 - 2.86	0.56 - 1.89	0.44 - 0.65	1.20 - 1.40	0.79 - 2.86	0.44 - 2.86
Underground	1.70 - 1.70	-	-	-	1.40 - 1.40	-	1.40 - 1.70
Walk	-	0.16 - 0.16	-	0.16 - 0.16	-	-	0.16 - 0.16
Motorcycle	1.60 - 1.60	-	0.74 - 1.75	1.52 - 1.52	-	1.16 - 1.65	0.74 - 1.75
Bicycle	-	0.06 - 0.06	-	0.06 - 0.06	-	-	0.06 - 0.06

1. The range assumes an occupancy of 25-50% for each mode.
2. Calculated from figures expressed in terms of litres per passenger-kilometre, assuming that 1 litre petroleum is equivalent to 35MJ.

It is possible to calculate a range of passenger transport energy consumption values by mode (Table A1.4) by combining information about passenger travel by mode (Table A1.2), the range of specific energy consumption (SEC) values (identified in Table A1.3) and population statistics for Great Britain. In the absence of literature on the SEC of modes such as taxis, minicabs, vans and lorries, assumptions about their energy efficiency were necessary. The SEC values for taxis, minicabs, vans and lorries were all assumed to be 50 per cent higher than the SEC values for cars. Hillman and Whalley (1983) suggest that the energy consumption of taxis may be between 33 and 190 per cent higher than cars due to the low occupancy of trips and the number of unoccupied return journeys. The SEC values for other public and other private modes were assumed to be the same as for buses and cars respectively.

TABLE A1.4 PASSENGER TRANSPORT ENERGY CONSUMPTION BY MODE CALCULATED USING THE BOTTOM-UP APPROACH

	Energy Consumption (PJ or 10^{15}J)			
Mode	*1985/86*	*1989/91*	*1991/93*	*1993/95*
Road excluding bus/coach	403-1755	518-2259	529-2313	541-2369
Bus/coach	13-71	13-68	12-66	11-62
Rail	17-81	21-102	19-88	19-85
Total	437-1906	555-2429	565-2466	577-2516

Sources: Tables A1.2 and A1.3 (above).

The wide range of figures for each mode (in Table A1.4) is a direct consequence of the wide range of SEC values used in calculating transport energy consumption. The results of the top-down and bottom-up approaches presented in Tables A1.1 and A1.4 show that there is broad agreement between the two approaches. SEC values at the low end of the range give rise to underestimates of passenger transport energy consumption whilst SEC values at the high end of the range give rise to overestimates of passenger transport energy consumption. Mid to low SEC values for road modes (excluding bus and coach) provide good convergence between the results of the top-down and the bottom-up approach. SEC values in the middle of the range for rail modes provide good convergence between the results of the top-down and the bottom-up approach. The SEC values for buses and coaches need to be towards the higher end of the range if the results of the top-down and bottom-up approaches are to converge. Thus, the SEC values chosen for use in the study are those that are between the lowest and mid-range value for road modes (excluding bus and coach), mid-range for rail modes and between mid-range and the upper end for buses and coaches. These are presented in Table A1.5.

TABLE A1.5 SEC VALUES CHOSEN FOR USE IN THIS STUDY

Mode	*SEC value (MJ/passenger-km)*	*Derivation*
Car	1.96	between the lowest and mid-range SEC value
Stage bus	1.28	between the mid-range and highest SEC value
Express bus	0.79	between the mid-range and highest SEC value
Heavy rail	1.65	mid-range SEC value
Underground	1.55	mid-range SEC value
Motorcycle/moped	0.99	between the lowest and mid-range SEC value
Bicycle	0.06	
Walk	0.16	
Van/lorry	2.94	assumed to be 50% higher than the SEC of a car
Taxi/minicab	2.94	assumed to be 50% higher than the SEC of a car
Other public	1.28	assumed to be the same as the SEC of a stage bus
Other private	1.96	assumed to be the same as the SEC of a car

APPENDIX 2: SOCIO-ECONOMIC AND LAND USE VARIABLES ANALYSED AT THE INDIVIDUAL LEVEL USING THE NATIONAL TRAVEL SURVEY DATA

Variable type	*Variable name*	*Value and description*	
1. Gender	MALE	=1	if male
2. Age	AGE0004	=1	if aged between 0 and 4
	AGE0510	=1	if aged between 5 and 10
	AGE1115	=1	if aged between 11 and 15
	AGE1619	=1	if aged between 16 and 19
	AGE2029	=1	if aged between 20 and 29
	AGE3039	=1	if aged between 30 and 39
	AGE4049	=1	if aged between 40 and 49
	AGE5059	=1	if aged between 50 and 59
	AGE6069	=1	if aged between 60 and 69
3. Employment status	WORKER	=1	if in paid employment (full-time or part-time)
	FTWORKER	=1	if in full-time paid work
	PTWORKER	=1	if in part-time paid work
	UNEMPLOY	=1	if unemployed
	RETIRED	=1	if retired
	STUDENT	=1	if a student
4. Possession of a driving licence	LICENCEP	=1	if provisional driving licence held
	LICENCEF	=1	if full driving licence held
5. Household size	PERSONS1	=1	if one person lives in the household
	PERSONS2	=1	if two people live in the household
	PERSONS3	=1	if three people live in the household
	PERSONS4	=1	if four people live in the household
	PERSONS5	=1	if five people live in the household
6. Household composition	ADULTS1	=1	if one adult lives in the household
	ADULTS2	=1	if two adults live in the household
	ADULTS3	=1	if three adults live in the household
	ADULTS4	=1	if four adults live in the household
	ADULTS5	=1	if five adults live in the household
	CHILD0	=1	if no children live in the household
	CHILD1	=1	if one child lives in the household
	CHILD2	=1	if two children live in the household
	CHILD3	=1	if three children live in the household
	CHILD4	=1	if four children live in the household
7. Socio-economic status	SEG1	=1	if head of household is in managerial employment
	SEG2	=1	if head of household is in skilled non-manual employment
	SEG3	=1	if head of household is in skilled manual employment
	SEG4	=1	if head of household is in semi-skilled employment
	SEG5	=1	if head of household is in unskilled employment
8. Household driving licence ownership	HHLICS0	=1	if no-one in the household has a full driving licence
	HHLICS1	=1	if one member of the household has a full driving licence
	HHLICS2	=1	if two members of the household have a full driving licence

Variable type	*Variable name*	*Value and description*	
9. Household structure	HHSTR1	=1	if there is only one person in the household and s/he is under 65 years old
	HHSTR2	=1	if there is only one person in the household and s/he is 65 years old or above
	HHSTR3	=1	if there are two members of the household and the head of the household is under 30 years old
	HHSTR4	=1	if there are two members of the household and the head of the household is between 30 and 64 years old
	HHSTR5	=1	if there are two members of the household and the head of the household is 65 years old or above
	HHSTR6	=1	if there are three members of the household in total and one or two of these are children
	HHSTR7	=1	if there are three adults in the household and no children
	HHSTR8	=1	if there are four members of the household in total and two or three of these are children
	HHSTR9	=1	if there are four members of the household in total and one of these is a child
	HHSTR10	=1	if there are four adults in the household in total and no children
	HHSTR11	=1	if there are five or more members of the household in total and three or more of these are children
	HHSTR12	=1	if there are five or more members of the household in total and one or two of these are children
10. Household car ownership	HHCARS0	=1	if the household owns no cars
	HHCARS1	=1	if the household owns one car
	HHCARS2	=1	if the household owns two cars
11. Householders in employment	WORKERS0	=1	if there are no members of the household in paid employment
	WORKERS1	=1	if there is one member of the household in paid employment
	WORKERS2	=1	if there are two members of the household in paid employment
12. Proximity to local facilities	LOCACCHI	=1	if the nearest chemist, post office and grocers are all within a 6 minute walk from home
	LOCACCLO	=1	if the nearest chemist, post office and grocers are all more than 44 minutes walk from home
13. Proximity to high street shops	CITY06	=1	if the nearest high street shops are within a 6 minute walk from home
	CITY13	=1	if the nearest high street shops are within a 7 to 13 minute walk from home
	CITY26	=1	if the nearest high street shops are within a 14 to 26 minute walk from home
	CITY43	=1	if the nearest high street shops are within a 27 to 43 minute walk from home
14. Proximity to a bus stop	BSTOP03	=1	if the nearest bus stop is within a 3 minute walk from home
	BSTOP06	=1	if the nearest bus stop is within a 4 to 6 minute walk from home
	BSTOP13	=1	if the nearest bus stop is within a 7 to 13 minute walk from home
	BSTOP26	=1	if the nearest bus stop is within a 14 to 26 minute walk from home
	BSTOP43	=1	if the nearest bus stop is within a 27 to 43 minute walk from home
15. Local bus frequency	BSFREQ1	=1	if the frequency of the bus service is less than 2 per hour
	BSFREQ2	=1	if the frequency of the bus service is between 2 and 4 per hour
16. Proximity to a railway station	RLYSTN06	=1	if the nearest railway station is within a 6 minute walk from home
	RLYSTN13	=1	if the nearest railway station is within a 7 to 13 minute walk from home
	RLYSTN26	=1	if the nearest railway station is within a 14 to 26 minute walk from home
	RLYSTN43	=1	if the nearest railway station is within a 27 to 43 minute walk from home

Variable type	*Variable name*	*Value and description*
17. Settlement size	SETT_LON	=1 if the household is in London
	SETT_MET	=1 if the household is in a large metropolitan area (Glasgow, Greater Manchester, Liverpool, Tyneside, West Midlands, West Yorkshire)
	SETT_250	=1 if the household is in a settlement containing more than 250,000 people (and not in any of the above metropolitan areas)
	SETT_100	=1 if the household is in a settlement containing between 100,000 and 250,000 residents
	SETT_050	=1 if the household is in a settlement containing between 50,000 and 100,000 residents
	SETT_025	=1 if the household is in a settlement containing between 25,000 and 50,000 residents
	SETT_003	=1 if the household is in a settlement containing between 3,000 and 10,000 residents
18. Ward-level population density	WDENS00	=1 if the household is in a ward where the population density is less than 10 persons per hectare
	WDENS10	=1 if the household is in a ward where the population density is between 10 and 20 persons per hectare
	WDENS20	=1 if the household is in a ward where the population density is between 20 and 30 persons per hectare
	WDENS30	=1 if the household is in a ward where the population density is between 30 and 40 persons per hectare
	WDENS40	=1 if the household is in a ward where the population density is between 40 and 50 persons per hectare
19. Local authority-level population density	LDENS00	=1 if the household is in a local authority where the population density is less than 5 persons per hectare
	LDENS05	=1 if the household is in a local authority where the population density is between 5 and 10 persons per hectare
	LDENS10	=1 if the household is in a local authority where the population density is between 10 and 15 persons per hectare
	LDENS15	=1 if the household is in a local authority where the population density is between 15 and 20 persons per hectare
	LDENS20	=1 if the household is in a ward where the population density is between 20 and 25 persons per hectare

Appendix 3: Results of the Regression of Average Distance per Person per Week at the Individual Level of Analysis: National Travel Survey Data

A3.1 Regression Analyses with Data from the 1978/79 National Travel Survey

Dependent Variable = Distance per person /
Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	LICENCEF	entered	0.14	0.14	3488	0.00
2.	FTWORKER	entered	0.17	0.17	2193	0.00
3.	HHCARS0	entered	0.19	0.19	1738	0.00
4.	SEG1	entered	0.20	0.20	1379	0.00
5.	HHCARS1	entered	0.21	0.21	1132	0.00
6.	LDENS20	entered	0.21	0.21	958	0.00
7.	MALE	entered	0.21	0.21	829	0.00
8.	LICENCEP	entered	0.21	0.21	732	0.00
9.	HHSTR3	entered	0.21	0.21	655	0.00
10.	AGE3039	entered	0.21	0.21	593	0.00
11.	WDENS00	entered	0.21	0.21	543	0.00
12.	SEG2	entered	0.22	0.21	500	0.00
13.	AGE5059	entered	0.22	0.22	463	0.00
14.	AGE0510	entered	0.22	0.22	431	0.00
15.	RETIRED	entered	0.22	0.22	405	0.00
16.	PERSONS5	entered	0.22	0.22	381	0.00
17.	AGE0004	entered	0.22	0.22	359	0.00
18.	HHLICS1	entered	0.22	0.22	340	0.00
19.	LDENS00	entered	0.22	0.22	323	0.00
20.	WDENS40	entered	0.22	0.22	307	0.00
21.	SEG4	entered	0.22	0.22	293	0.00
22.	SEG3	entered	0.22	0.22	281	0.00
23.	SEG5	entered	0.22	0.22	269	0.00
24.	SEG2	removed	0.22	0.22	282	0.00
25.	PTWORKER	entered	0.22	0.22	270	0.00
26.	WORKERS1	entered	0.22	0.22	259	0.00
27.	WORKERS0	entered	0.22	0.22	249	0.00
28.	AGE6069	entered	0.22	0.22	240	0.00
29.	STUDENT	entered	0.22	0.22	231	0.00
30.	HHSTR5	entered	0.22	0.22	223	0.00
31.	ADULTS2	entered	0.22	0.22	216	0.00
32.	RLYSTN43	entered	0.22	0.22	209	0.00
33.	RLYSTN26	entered	0.22	0.22	202	0.00
34.	RLYSTN13	entered	0.22	0.22	196	0.00
35.	WDENS30	entered	0.22	0.22	191	0.00
36.	BSTOP06	entered	0.22	0.22	185	0.00
37.	HHCARS2	entered	0.22	0.22	180	0.00

Multiple R	0.473
R Square	0.224
Adjusted R Square	0.223
Standard Error	165.090
Mean Absolute Deviation	103

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
MALE	26.640	2.588	0.071	1.344	10.293	0.000
AGE0004	-22.692	5.213	-0.030	1.313	-4.353	0.000
AGE0510	-22.936	4.422	-0.037	1.433	-5.187	0.000
AGE3039	7.142	3.739	0.013	1.350	1.910	0.056
AGE5059	-22.267	3.842	-0.038	1.192	-5.796	0.000
AGE6069	-10.577	4.179	-0.017	1.311	-2.531	0.011
FTWORKER	75.862	3.673	0.195	2.512	20.657	0.000
PTWORKER	21.059	4.831	0.031	1.466	4.359	0.000
RETIRED	-20.334	5.006	-0.032	1.697	-4.062	0.000
STUDENT	59.803	20.439	0.018	1.025	2.926	0.003
LICENCEP	23.541	5.761	0.026	1.123	4.086	0.000
LICENCEF	61.842	3.313	0.158	2.024	18.668	0.000
PERSONS5	-12.796	3.405	-0.023	1.079	-3.758	0.000
ADULTS2	6.970	2.758	0.018	1.430	2.527	0.012
SEG1	32.212	3.386	0.065	1.296	9.514	0.000
SEG3	-17.030	2.790	-0.042	1.329	-6.104	0.000
SEG4	-22.021	3.915	-0.037	1.218	-5.624	0.000
SEG5	-22.039	5.422	-0.026	1.115	-4.065	0.000
HHLICS1	-8.064	2.508	-0.021	1.219	-3.216	0.001
HHSTR3	26.701	6.545	0.026	1.150	4.080	0.000
HHSTR5	-16.383	5.140	-0.025	1.695	-3.187	0.001
HHCARS0	-112.441	11.453	-0.292	24.880	-9.817	0.000
HHCARS1	-59.417	11.321	-0.159	25.755	-5.248	0.000
HHCARS2	-23.557	11.587	-0.038	9.792	-2.033	0.042
WORKERS0	20.491	4.645	0.041	2.411	4.411	0.000
WORKERS1	11.354	2.798	0.029	1.407	4.058	0.000
BSTOP06	8.337	3.545	0.014	1.008	2.352	0.019
RLYSTN13	-9.979	4.045	-0.015	1.088	-2.467	0.014
RLYSTN26	-8.779	3.000	-0.019	1.129	-2.927	0.003
RLYSTN43	-10.670	3.187	-0.021	1.110	-3.348	0.001
WDENS00	7.935	3.563	0.017	1.673	2.227	0.026
WDENS30	7.470	3.223	0.015	1.133	2.318	0.021
WDENS40	-7.261	3.656	-0.013	1.132	-1.986	0.047
LDENS00	9.863	3.384	0.023	1.721	2.914	0.004
LDENS20	-11.106	2.662	-0.028	1.300	-4.171	0.000
(Constant)	177.575	11.701			15.176	0.000

A3.2 Regression Analyses with Data from the 1985/86 National Travel Survey

Dependent Variable = Distance per person /
Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	LICENCEF	entered	0.13	0.13	3657	0.00
2.	FTWORKER	entered	0.17	0.17	2531	0.00
3.	SEG1	entered	0.19	0.19	1943	0.00
4.	HHCARS0	entered	0.21	0.21	1583	0.00
5.	HHCARS1	entered	0.22	0.22	1361	0.00
6.	WDENS00	entered	0.22	0.22	1160	0.00
7.	SEG2	entered	0.23	0.23	1017	0.00
8.	MALE	entered	0.23	0.23	901	0.00
9.	HHCARS2	entered	0.23	0.23	809	0.00
10.	HHLICS0	entered	0.23	0.23	734	0.00
11.	STUDENT	entered	0.23	0.23	672	0.00
12.	HHSTR1	entered	0.23	0.23	619	0.00
13.	ADULTS2	entered	0.23	0.23	575	0.00
14.	HHSTR3	entered	0.24	0.24	536	0.00
15.	AGE3039	entered	0.24	0.24	502	0.00
16.	LOCACCHI	entered	0.24	0.24	473	0.00
17.	HHSTR11	entered	0.24	0.24	447	0.00
18.	RETIRED	entered	0.24	0.24	423	0.00
19.	AGE0510	entered	0.24	0.24	402	0.00
20.	HHSTR2	entered	0.24	0.24	383	0.00
21.	BSFREQ2	entered	0.24	0.24	365	0.00
22.	SETT_100	entered	0.24	0.24	349	0.00
23.	SEG4	entered	0.24	0.24	334	0.00
24.	HHSTR10	entered	0.24	0.24	321	0.00
25.	AGE2029	entered	0.24	0.24	308	0.00
26.	PTWORKER	entered	0.24	0.24	297	0.00
27.	WORKERS1	entered	0.24	0.24	286	0.00
28.	PBSTOP06	entered	0.24	0.24	276	0.00
29.	PBSTOP03	entered	0.24	0.24	267	0.00
30.	PBSTOP13	entered	0.24	0.24	259	0.00
31.	SETT_LON	entered	0.24	0.24	251	0.00
32.	HHSTR5	entered	0.24	0.24	243	0.00
33.	AGE0004	entered	0.24	0.24	236	0.00

Multiple R	0.493
R Square	0.242
Adjusted R Square	0.242
Standard Error	183.267
Mean Absolute Deviation	114

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
MALE	26.790	2.623	0.064	1.246	10.212	0.000
AGE0004	-12.562	5.473	-0.015	1.322	-2.295	0.022
AGE0510	-23.263	5.172	-0.030	1.384	-4.498	0.000
AGE2029	12.415	4.632	0.017	1.228	2.680	0.007
AGE3039	14.638	3.675	0.025	1.255	3.983	0.000
FTWORKER	87.979	3.622	0.201	2.194	24.293	0.000
PTWORKER	13.290	4.802	0.018	1.357	2.768	0.006
RETIRED	-15.289	4.834	-0.025	2.021	-3.163	0.002
STUDENT	42.801	7.872	0.032	1.130	5.437	0.000
LICENCEF	60.450	3.410	0.143	2.086	17.726	0.000
ADULTS2	14.256	3.093	0.033	1.664	4.609	0.000
SEG1	55.283	3.132	0.112	1.302	17.654	0.000

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
SEG2	31.200	3.162	0.061	1.222	9.868	0.000
SEG4	-12.276	4.109	-0.018	1.147	-2.988	0.003
HHLICS0	32.061	5.058	0.061	2.982	6.339	0.000
HHSTR1	38.400	6.327	0.038	1.263	6.070	0.000
HHSTR2	16.093	7.047	0.016	1.569	2.284	0.022
HHSTR3	26.918	6.515	0.025	1.219	4.132	0.000
HHSTR5	-12.922	5.376	-0.017	1.639	-2.404	0.016
HHSTR10	-16.988	5.789	-0.018	1.200	-2.934	0.003
HHSTR11	-18.906	4.277	-0.026	1.134	-4.420	0.000
HHCARS0	-172.043	7.581	-0.366	8.361	-22.694	0.000
HHCARS1	-107.031	6.517	-0.254	7.693	-16.424	0.000
HHCARS2	-55.876	6.617	-0.106	5.030	-8.445	0.000
WORKERS1	7.393	2.748	0.016	1.159	2.690	0.007
LOCACCHI	-11.480	2.762	-0.024	1.095	-4.156	0.000
BSTOP03	-31.935	6.163	-0.075	6.726	-5.182	0.000
BSTOP06	-36.248	6.317	-0.078	5.920	-5.738	0.000
BSTOP13	-28.215	7.008	-0.039	3.067	-4.026	0.000
BSFREQ2	-6.681	2.477	-0.015	1.038	-2.697	0.007
SETT_LON	-8.838	3.703	-0.014	1.115	-2.387	0.017
SETT_100	10.076	3.937	0.015	1.055	2.559	0.011
WDENS00	23.989	2.790	0.053	1.199	8.597	0.000
(Constant)	204.251	9.216			22.163	0.000

A3.3 Regression Analyses with Data from the 1989/91 National Travel Survey

Dependent Variable = Distance per person /
Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	FTWORKER	entered	0.12	0.12	3445	0.00
2.	LICENCEF	entered	0.16	0.16	2425	0.00
3.	SEG1	entered	0.18	0.18	1870	0.00
4.	HHCARS2	entered	0.20	0.20	1526	0.00
5.	WDENS00	entered	0.20	0.20	1278	0.00
6.	HHCARS0	entered	0.21	0.21	1099	0.00
7.	SEG2	entered	0.21	0.21	954	0.00
8.	MALE	entered	0.21	0.21	847	0.00
9.	HHCARS1	entered	0.21	0.21	761	0.00
10.	HHCARS2	removed	0.21	0.21	856	0.00
11.	BSFREQ1	entered	0.22	0.22	766	0.00
12.	WORKERS1	entered	0.22	0.22	694	0.00
13.	HHSTR3	entered	0.22	0.22	634	0.00
14.	AGE3039	entered	0.22	0.22	586	0.00
15.	STUDENT	entered	0.22	0.22	544	0.00
16.	HHLICS0	entered	0.22	0.22	507	0.00
17.	ADULTS2	entered	0.22	0.22	474	0.00
18.	HHSTR1	entered	0.22	0.22	446	0.00
19.	AGE4049	entered	0.22	0.22	421	0.00
20.	AGE1115	entered	0.22	0.22	399	0.00
21.	WDENS10	entered	0.22	0.22	379	0.00
22.	SEG4	entered	0.22	0.22	360	0.00
23.	PERSONS3	entered	0.22	0.22	344	0.00
24.	WORKER	entered	0.22	0.22	329	0.00
25.	WORKERS0	entered	0.22	0.22	315	0.00
26.	HHLICS1	entered	0.22	0.22	303	0.00
27.	HHLICS0	removed	0.22	0.22	316	0.00
28.	UNEMPLOY	entered	0.23	0.22	304	0.00
29.	PERSONS1	entered	0.23	0.22	292	0.00
30.	HHSTR1	removed	0.23	0.22	304	0.00
31.	SETT_250	entered	0.23	0.22	292	0.00
32.	SETT_LON	entered	0.23	0.23	282	0.00
33.	SETT_MET	entered	0.23	0.23	272	0.00
34.	BSTOP43	entered	0.23	0.23	263	0.00
35.	SETT_025	entered	0.23	0.23	254	0.00
36.	BSTOP26	entered	0.23	0.23	246	0.00
37.	AGE1619	entered	0.23	0.23	238	0.00
38.	ADULTS5	entered	0.23	0.23	231	0.00
39.	CHILD3	entered	0.23	0.23	224	0.00
40.	LDENS05	entered	0.23	0.23	218	0.00
41.	BSFREQ2	entered	0.23	0.23	212	0.00
42.	LOCACCHI	entered	0.23	0.23	206	0.00

Multiple R	0.478
R Square	0.228
Adjusted R Square	0.227
Standard Error	211.562
Mean Absolute Deviation	136

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
MALE	29.169	2.943	0.061	1.213	9.912	0.000
AGE1115	32.035	6.155	0.032	1.218	5.204	0.000
AGE1619	-19.510	7.790	-0.018	1.601	-2.504	0.012
AGE3039	23.614	4.364	0.034	1.316	5.412	0.000
AGE4049	13.651	4.442	0.019	1.305	3.073	0.002
WORKER	35.309	5.857	0.073	4.791	6.029	0.000
FTWORKER	92.344	5.179	0.185	3.508	17.832	0.000
UNEMPLOY	37.943	8.300	0.027	1.123	4.571	0.000
STUDENT	86.575	10.031	0.059	1.536	8.631	0.000
LICENCEF	55.688	3.793	0.116	2.017	14.684	0.000
PERSONS1	27.985	5.846	0.035	1.744	4.787	0.000
PERSONS3	10.178	3.637	0.017	1.183	2.798	0.005
ADULTS2	19.483	3.450	0.040	1.602	5.647	0.000
ADULTS5	-29.469	11.688	-0.014	1.062	-2.521	0.012
CHILD3	-13.443	5.241	-0.015	1.099	-2.565	0.010
SEG1	60.723	3.446	0.112	1.317	17.621	0.000
SEG2	25.929	3.617	0.044	1.244	7.169	0.000
SEG4	-13.455	4.725	-0.017	1.142	-2.847	0.004
HHLICS1	-17.055	3.295	-0.033	1.330	-5.177	0.000
HHSTR3	46.577	7.216	0.038	1.156	6.455	0.000
HHCARS0	-111.737	5.007	-0.196	2.499	-22.316	0.000
HHCARS1	-56.410	3.668	-0.117	1.880	-15.379	0.000
WORKERS0	23.579	5.322	0.041	2.745	4.430	0.000
WORKERS1	26.645	3.671	0.049	1.507	7.258	0.000
LOCACCHI	-6.718	3.083	-0.013	1.071	-2.179	0.029
BSTOP26	23.036	9.619	0.013	1.031	2.395	0.017
BSTOP43	-55.710	19.123	-0.016	1.016	-2.913	0.004
BSFREQ1	21.697	5.169	0.027	1.324	4.197	0.000
BSFREQ2	-6.505	2.907	-0.013	1.074	-2.238	0.025
SETT_LON	-24.691	4.706	-0.033	1.298	-5.247	0.000
SETT_MET	-22.126	4.306	-0.033	1.302	-5.138	0.000
SETT_250	-22.859	4.332	-0.032	1.220	-5.277	0.000
SETT_025	-14.514	4.969	-0.017	1.122	-2.921	0.004
WDENS00	25.074	3.626	0.048	1.553	6.915	0.000
WDENS10	8.443	4.327	0.012	1.142	1.951	0.051
LDENS05	-9.324	4.187	-0.013	1.048	-2.227	0.026
(Constant)	117.386	5.991			19.595	0.000

A3.4 Regression Analyses with Data from the 1991/93 National Travel Survey

Dependent Variable = Distance per person /
Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	FTWORKER	entered	0.11	0.11	3043	0.00
2.	LICENCEF	entered	0.15	0.15	2141	0.00
3.	SEG1	entered	0.18	0.18	1725	0.00
4.	HHCARS2	entered	0.19	0.19	1409	0.00
5.	WDENS00	entered	0.20	0.20	1176	0.00
6.	HHCARS0	entered	0.20	0.20	1015	0.00
7.	HHCARS1	entered	0.20	0.20	883	0.00
8.	HHCARS2	removed	0.20	0.20	1030	0.00
9.	SEG2	entered	0.21	0.21	896	0.00
10.	MALE	entered	0.21	0.21	795	0.00
11.	BSFREQ1	entered	0.21	0.21	715	0.00
12.	PTWORKER	entered	0.21	0.21	648	0.00
13.	SETT_LON	entered	0.21	0.21	593	0.00
14.	STUDENT	entered	0.21	0.21	547	0.00
15.	AGE1619	entered	0.22	0.21	508	0.00
16.	ADULTS3	entered	0.22	0.22	474	0.00
17.	PERSONS5	entered	0.22	0.22	444	0.00
18.	UNEMPLOY	entered	0.22	0.22	417	0.00
19.	ADULTS4	entered	0.22	0.22	393	0.00
20.	HHLICS0	entered	0.22	0.22	372	0.00
21.	ADULTS5	entered	0.22	0.22	353	0.00
22.	LDENS10	entered	0.22	0.22	336	0.00
23.	HHSTR1	entered	0.22	0.22	321	0.00
24.	HHSTR3	entered	0.22	0.22	307	0.00
25.	AGE4049	entered	0.22	0.22	294	0.00
26.	AGE1115	entered	0.22	0.22	282	0.00
27.	AGE3039	entered	0.22	0.22	271	0.00
28.	SETT_250	entered	0.22	0.22	261	0.00
29.	SETT_MET	entered	0.22	0.22	252	0.00
30.	WORKERS1	entered	0.22	0.22	243	0.00
31.	SEG4	entered	0.22	0.22	235	0.00
32.	BSTOP13	entered	0.22	0.22	227	0.00

Multiple R	0.470
R Square	0.221
Adjusted R Square	0.220
Standard Error	216.316
Mean Absolute Deviation	136

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
MALE	29.712	3.025	0.061	1.176	9.822	0.000
AGE1115	18.469	6.170	0.018	1.169	2.993	0.003
AGE1619	-32.167	8.618	-0.028	1.681	-3.732	0.000
AGE3039	12.111	4.529	0.018	1.333	2.674	0.008
AGE4049	17.384	4.581	0.025	1.314	3.795	0.000
FTWORKER	117.386	4.292	0.229	2.154	27.349	0.000
PTWORKER	38.207	5.506	0.046	1.370	6.939	0.000
UNEMPLOY	23.175	7.833	0.018	1.171	2.959	0.003
STUDENT	82.411	9.922	0.061	1.647	8.306	0.000
LICENCEF	59.126	3.929	0.121	1.981	15.050	0.000
PERSONS5	-14.523	4.926	-0.018	1.111	-2.948	0.003
ADULTS3	-21.519	4.155	-0.033	1.242	-5.179	0.000
ADULTS4	-17.687	6.132	-0.018	1.233	-2.884	0.004

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
ADULTS5	-33.435	13.450	-0.015	1.100	-2.486	0.013
SEG1	72.092	3.592	0.132	1.329	20.070	0.000
SEG2	27.163	3.750	0.046	1.255	7.244	0.000
SEG4	-10.814	5.011	-0.013	1.153	-2.158	0.031
HHLICS0	23.039	6.540	0.034	2.843	3.523	0.000
HHSTR1	18.651	6.629	0.017	1.161	2.814	0.005
HHSTR3	31.271	7.617	0.025	1.145	4.105	0.000
HHCARS0	-124.343	6.067	-0.211	3.260	-20.495	0.000
HHCARS1	-62.408	3.522	-0.127	1.589	-17.719	0.000
WORKERS1	7.147	3.269	0.013	1.090	2.187	0.029
BSTOP13	10.441	5.183	0.012	1.011	2.014	0.044
BSFREQ1	39.595	5.313	0.047	1.208	7.452	0.000
SETT_LON	-33.852	4.720	-0.045	1.214	-7.172	0.000
SETT_MET	-11.160	4.348	-0.016	1.226	-2.567	0.010
SETT_250	-13.859	4.662	-0.018	1.138	-2.973	0.003
WDENS00	19.559	3.649	0.037	1.443	5.360	0.000
LDENS10	-14.556	5.300	-0.016	1.092	-2.746	0.006
(Constant)	138.656	5.233			26.495	0.000

A3.5 Summary of Results For Regression Analyses where the Dependent Variable is Distance per Person and the Independent Variables are Socio-Economic and Land Use Characteristics

Data source → *Independent variable* [1] ↓	*NTS 1978/79*	*NTS 1985/86*	*NTS 1989/91*	*NTS 1991/93*	*Comments*
MALE	+ +	+ +	+ +	++	Men travel further than women.
AGE0004	–	–			People aged between 30 and 39 travel more than most other age groups, particularly children.
AGE0510	–	–			
AGE1115			+	+	
AGE1619			–	–	
AGE2029		+			
AGE3039	+	+	+	+	
AGE4049			+	+	
AGE5059	–				
AGE6069	–				
LICENCEP	+				People with a driving licence travel further than those with only a provisional licence and those without a licence.
LICENCEF	+ + +	+ + +	+ + +	+ + +	
FTWORKER	+ + +	+ + +	+ + +	+ + +	People in full-time work travel further than people in part-time work and those not in work. Students travel more than most other categories.
PTWORKER	+	+		+	
UNEMPLOY			+	+	
RETIRED	–	–			
STUDENT	+	+	+ +	+ +	
WORKERS0	+		+		Residents of households in which one person is in employment often travel further than the residents of other types of household.
WORKERS1	+	+	+	+	
WORKERS2					
PERSONS1			+		No conclusions about the effect of household size on travel distance.
PERSONS2					
PERSONS3			+		
PERSONS4					
PERSONS5	–			–	
ADULTS1					Residents of households containing one or two adults travel further than residents of households containing more adults.
ADULTS2	+	+	+		
ADULTS3				–	
ADULTS4				–	
ADULTS5			–	–	
CHILD0					The number of children in the household does not appear to have any great effect on travel distance per person.
CHILD1					
CHILD2					
CHILD3			–		
CHILD4					
SEG1	+ +	+ + +	+ + +	+ + +	Residents of households in socio-economic group 1 travel the furthest, whilst residents of households in socio-economic groups 4 travel the least.
SEG2		+ +	+	+	
SEG3	–				
SEG4	–	–	–	–	
SEG5	–				
HHLICS0		+ +		+	No conclusions about the effect of the number of people with driving licences in the household on travel distance per person.
HHLICS1	–		–		
HHLICS2					

1. Refer to Appendix 2 for an explanation of the independent variables included in the regression analysis.

Data source → *Independent variable*[1] ↓	*NTS 1978/79*	*NTS 1985/86*	*NTS 1989/91*	*NTS 1991/93*	*Comments*
HHSTR1		+		+	Residents of households containing two adults and no children (where the head of the household is under 30 years old) travel more than other types of households.
HHSTR2		+			
HHSTR3	+	+	+	+	
HHSTR4					
HHSTR5	–	–			
HHSTR6					
HHSTR7					
HHSTR8					
HHSTR9					
HHSTR10		–			
HHSTR11		–			
HHSTR12					
HHCARS0	– – –	– – –	– – –	– – –	People in households with two or more cars travel further than residents of households with fewer than two cars.
HHCARS1	– – –	– – –	– – –	– – –	
HHCARS2	–	– – –			
LOCACCHI		–	–		No conclusions about the effect of the proximity to local facilities (post office, chemist and grocers) on travel distance.
LOCACCLO					
CITY06					The distance from home to the nearest high street shops does not appear to have any effect on travel distance.
CITY13					
CITY26					
CITY43					
BSTOP03		– –			No conclusions about the effect of the proximity to a bus stop on travel distance.
BSTOP06	+	– –			
BSTOP13		–		+	
BSTOP26			+		
BSTOP43			–		
BSFREQ1			+	+	Residents of areas with higher bus frequencies (more than one bus every hour) now travel shorter distances.
BSFREQ2		–	–		
RLYSTN06					No conclusions about the effect of the proximity to a railway station on travel distance.
RLYSTN13	–				
RLYSTN26	–				
RLYSTN43	–				
SETT_LON		–	–	–	No conclusions about the effect of settlement size on travel distance.
SETT_MET			–	–	
SETT_250			–	–	
SETT_100		+			
SETT_050					
SETT_025			–		
SETT_003			+		
WDENS00	+	+ +	+	+	Residents of low-density wards (under 10 persons per hectare) travel further than the residents of most other wards.
WDENS10			+		
WDENS20					
WDENS30	+				
WDENS40	–				
LDENS00	+				No conclusions about the effect of local authority population density on travel distance.
LDENS05	n.a.		–		
LDENS10	n.a.			–	
LDENS15	n.a.				
LDENS20	–				

1. Refer to Appendix 2 for an explanation of the independent variables included in the regression analysis.

Data source → *Independent variable* [1] ↓	*NTS 1978/79*	*NTS 1985/86*	*NTS 1989/91*	*NTS 1991/93*	*Comments*
Usable sample size (number of individuals)	21,888	24,357	25,104	24,067	

Notes:

+ + + = high positive relationship (beta weight^2>= 0.10)

+ + = medium positive relationship (beta weight^2 >= 0.05 and < 0.10)

\+ = low positive relationship (beta weight^2 >= 0.01 and < 0.05)

– – – = high negative relationship (beta weight^2 >= 0.10)

– – = medium negative relationship (beta weight^2 >= 0.05 and < 0.10)

– = low negative relationship (beta weight^2 >= 0.01 and < 0.05)

1. Refer to Appendix 2 for an explanation of the independent variables included in the regression analysis.

2. The partial regression coefficients from multiple regression depend on the units of the dependent and independent variables. They are scale-dependent and cannot be directly compared – higher partial regression coefficients do not necessarily imply more statistical importance or significance. Direct comparisons of the importance of independent variables are more appropriately made using *beta weights*, which are 'standardised' partial regression coefficients. The larger the numerical value of the beta weight, either negative or positive, the greater its importance in accounting for the behaviour of the dependent term (Shaw and Wheeler, 1994 p.252).

APPENDIX 4: SOCIO-ECONOMIC AND LAND USE VARIABLES ANALYSED AT THE SURVEY AREA LEVEL USING THE NATIONAL TRAVEL SURVEY DATA

Variable type	Variable name	Description
1. Age	PAGE0004	percentage of residents aged under 4 years
	PAGE0510	percentage of residents aged between 5 and 10 years
	PAGE1115	percentage of residents aged between 11 and 15 years
	PAGE1619	percentage of residents aged between 16 and 29 years
	PAGE2029	percentage of residents aged between 20 and 29 years
	PAGE3039	percentage of residents aged between 30 and 39 years
	PAGE4049	percentage of residents aged between 40 and 49 years
	PAGE5059	percentage of residents aged between 50 and 59 years
	PAGE6069	percentage of residents aged between 60 and 69 years
2. Employment status	PFTWRKRS	percentage of residents in part-time paid employment
	PPTWRKRS	percentage of residents in full-time paid employment
	PUNEMPLO	percentage of unemployed residents
	PRETIRED	percentage of retired residents
	PSTUDENT	percentage of residents who are students
3. Driving licence	PLICENC0	percentage of residents without a driving licence
	PLICENCF	percentage of residents with a full driving licence
4. Household size	PHHSIZE1	percentage of one-person households
	PHHSIZE2	percentage of two-person households
	PHHSIZE3	percentage of three-person households
	PHHSIZE4	percentage of four-person households
	PHHSIZE5	percentage of five-person households
	PHHSIZE6	percentage of households containing six or more residents
5. Household composition	PADULTS1	percentage of one-adult households
	PADULTS2	percentage of two-adult households
	PADULTS3	percentage of three-adult households
	PADULTS4	percentage of four-adult households
	PADULTS5	percentage of five-adult households
	PCHILD0	percentage of households without children
	PCHILD1	percentage of households with one child
	PCHILD2	percentage of households with two children
	PCHILD3	percentage of households with three children
	PCHILD4	percentage of households with four children
6. Socio-economic status	PSEG1	percentage of households whose head is in managerial employment
	PSEG2	percentage of households whose head is in skilled non-manual employment
	PSEG3	percentage of households whose head is in skilled manual employment
	PSEG4	percentage of households whose head is in semi-skilled employment
	PSEG5	percentage of households whose head is in unskilled employment
7. Household driving licence ownership	PHHLICS0	percentage of households without a driving licence
	PHHLICS1	percentage of households with one driving licence
	PHHLICS2	percentage of households with two driving licences

Variable type	Variable name	Description
8. Household structure	PHHSTR1	percentage of households containing only one person and s/he is under 65 years old
	PHHSTR2	percentage of households containing only one person and s/he is 65 years old or above
	PHHSTR3	percentage of households containing two members and the head of the household is under 30 years old
	PHHSTR4	percentage of households containing two members and the head of the household is between 30 and 64 years old
	PHHSTR5	percentage of households containing two members and the head of the household is 65 years old or above
	PHHSTR6	percentage of households containing three members in total and one or two of these are children
	PHHSTR7	percentage of households containing three adults and no children
	PHHSTR8	percentage of households containing four members in total and two or three of these are children
	PHHSTR9	percentage of households containing four members in total and one of these is a child
	PHHSTR10	percentage of households containing four adults in the household and no children
	PHHSTR11	percentage of households containing five or more members in total and three or more of these are children
	PHHSTR12	percentage of households containing five or more members in total and one or two of these are children
9. Household car ownership	PHHCARS0	percentage of households with no car
	PHHCARS1	percentage of households with one car
	PHHCARS2	percentage of households with two cars
	CARSPP	number of cars per person
10. Householders in employment	PWORKRS0	percentage of households with no residents in paid employment
	PWORKRS1	percentage of households with one resident in paid employment
	PWORKRS2	percentage of households with two residents in paid employment
	PWORKERS	percentage of residents in paid employment (as a proportion of the total population)
11. Proximity to local facilities	PLOCACHI	proportion of households within a 6 minute walk to the nearest chemist, post office and grocers
	PLOCACLO	proportion of households with more than a 44 minute walk to the nearest chemist, post office and grocers.
12. Proximity to high street shops	PCITY06	proportion of households within a 6 minute walk to the nearest high street shops
	PCITY13	proportion of households within a 7 to 13 minute walk to the nearest high street shops
	PCITY26	percentage of households within a 14 to 26 minute walk to the nearest high street shops
	PCITY43	percentage of households within a 27 to 43 minute walk to the nearest high street shops
13. Proximity to a bus stop	PBSTOP03	percentage of households within a 3 minute walk to the nearest bus stop
	PBSTOP06	percentage of households within a 4 to 6 minute walk to the nearest bus stop
	PBSTOP13	percentage of households within a 7 to 13 minute walk to the nearest bus stop
	PBSTOP26	percentage of households within a 14 to 26 minute walk to the nearest bus stop
	PBSTOP43	percentage of households within a 27 to 43 minute walk to the nearest bus stop
14. Local bus frequency	PBSFREQ1	percentage of households served by a bus route with a frequency of less than 2 buses per hour
	PBSFREQ2	percentage of households served by a bus route with a frequency of between 2 and 4 buses per hour

Variable type	Variable name		Description
15. Proximity to a railway station	PRLY06		percentage of households within a 6 minute walk to the nearest railway station
	PRLY13		percentage of households within a 7 to 13 minute walk of the nearest railway station
	PRLY26		percentage of households within a 14 to 26 minute walk to the nearest railway station
	PRLY43		percentage of households within a 27 to 43 minute walk to the nearest railway station
16. Settlement size	SETT_LON	=1	if the household is in London
	SETT_MET	=1	if the household is in a large metropolitan area (Glasgow, Greater Manchester, Liverpool, Tyneside, West Midlands, West Yorkshire)
	SETT_250	=1	if the household is in a settlement containing more than 250,000 people (and not in any of the above metropolitan areas)
	SETT_100	=1	if the household is in a settlement containing between 100,000 and 250,000 residents
	SETT_050	=1	if the household is in a settlement containing between 50,000 and 100,000 residents
	SETT_025	=1	if the household is in a settlement containing between 25,000 and 50,000 residents
	SETT_003	=1	if the household is in a settlement containing between 3,000 and 10,000 residents
17. Ward-level population density	WDENS00	=1	if the household is in a ward where the population density is less than 10 persons per hectare
	WDENS10	=1	if the household is in a ward where the population density is between 10 and 20 persons per hectare
	WDENS20	=1	if the household is in a ward where the population density is between 20 and 30 persons per hectare
	WDENS30	=1	if the household is in a ward where the population density is between 30 and 40 persons per hectare
	WDENS40	=1	if the household is in a ward where the population density is between 40 and 50 persons per hectare
18. Local authority-level population density	LDENS00	=1	if the household is in a local authority where the population density is less than 5 persons per hectare
	LDENS05	=1	if the household is in a local authority where the population density is between 5 and 10 persons per hectare
	LDENS10	=1	if the household is in a local authority where the population density is between 10 and 15 persons per hectare
	LDENS15	=1	if the household is in a local authority where the population density is between 15 and 20 persons per hectare
	LDENS20	=1	if the household is in a ward where the population density is between 20 and 25 persons per hectare

APPENDIX 5: RESULTS OF THE REGRESSION OF AVERAGE DISTANCE PER PERSON PER WEEK AT THE SURVEY AREA LEVEL OF ANALYSIS: NATIONAL TRAVEL SURVEY DATA

A5.1 REGRESSION ANALYSES WITH DATA FROM THE 1978/79 NATIONAL TRAVEL SURVEY

A5.1.1 Dependent Variable = Distance per person / Independent Variables = Land Use and Socio-Economic Variables

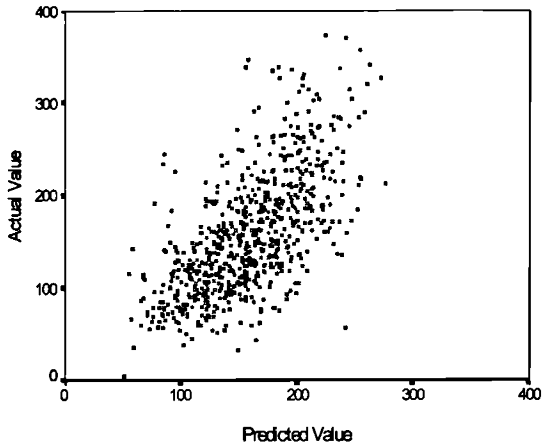
Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.31	0.31	9927	0.00
2.	PSEG1	entered	0.35	0.35	5531	0.00
3.	LDENS20	entered	0.37	0.37	4010	0.00
4.	PHHLICS2	entered	0.38	0.38	3176	0.00
5.	PSEG3	entered	0.39	0.39	2634	0.00
6.	PCITY13	entered	0.39	0.39	2268	0.00
7.	PFTWRKRS	entered	0.40	0.40	2015	0.00
8.	PHHLICS0	entered	0.40	0.40	1803	0.00
9.	LDENS00	entered	0.41	0.41	1635	0.00
10.	PSEG2	entered	0.41	0.41	1499	0.00
11.	PHHSTR2	entered	0.41	0.41	1380	0.00
12.	PSTUDENT	entered	0.42	0.42	1281	0.00
13.	PBSTOP06	entered	0.42	0.42	1192	0.00
14.	PAGE2029	entered	0.42	0.42	1118	0.00
15.	PCITY26	entered	0.42	0.42	1052	0.00
16.	WDENS30	entered	0.43	0.43	992	0.00
17.	PHHSTR9	entered	0.43	0.43	940	0.00
18.	PAGE3039	entered	0.43	0.43	895	0.00
19.	PAGE4049	entered	0.43	0.43	853	0.00
20.	PHHSTR4	entered	0.43	0.43	816	0.00
21.	PBSTOP26	entered	0.43	0.43	781	0.00
22.	PHHSTR3	entered	0.43	0.43	750	0.00
23.	PCITY43	entered	0.43	0.43	721	0.00
24.	WDENS20	entered	0.43	0.43	694	0.00
25.	SETT_100	entered	0.43	0.43	669	0.00
26.	PHHSTR11	entered	0.43	0.43	646	0.00
27.	PBSTOP13	entered	0.43	0.43	625	0.00
28.	PSEG4	entered	0.44	0.43	605	0.00
29.	PRLY06	entered	0.44	0.44	586	0.00
30.	PRLY43	entered	0.44	0.44	568	0.00
31.	PAGE0510	entered	0.44	0.44	551	0.00
32.	PSEG5	entered	0.44	0.44	535	0.00
33.	PHHLICS1	entered	0.44	0.44	520	0.00
34.	PHHLICS0	removed	0.44	0.44	536	0.00
35.	PRLY13	entered	0.44	0.44	521	0.00
36.	PAGE1619	entered	0.44	0.44	507	0.00
37.	PHHSTR11	entered	0.44	0.44	493	0.00
38.	PHHSTR7	entered	0.44	0.44	480	0.00
39.	PAGE5059	entered	0.44	0.44	468	0.00
40.	PAGE6069	entered	0.44	0.44	458	0.00
41.	PLOCACLO	entered	0.44	0.44	447	0.00

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
42.	PHHSTR2	entered	0.44	0.44	436	0.00
43.	PRETIRED	entered	0.44	0.44	426	0.00
44.	PUNEMPLO	entered	0.44	0.44	416	0.00
45.	WDENS40	entered	0.44	0.44	407	0.00
46.	SETT_LON	entered	0.44	0.44	398	0.00
47.	SETT_250	entered	0.45	0.44	389	0.00
48.	PHHSTR10	entered	0.45	0.44	381	0.00
49.	PAGE1115	entered	0.45	0.44	373	0.00
50.	SETT_MET	entered	0.45	0.44	366	0.00
51.	SETT_025	entered	0.45	0.44	358	0.00
52.	WDENS00	entered	0.45	0.44	352	0.00
53.	PBSFREQ2	entered	0.45	0.44	345	0.00
54.	PBSTOP43	entered	0.45	0.44	338	0.00
55.	PBSFREQ1	entered	0.45	0.44	332	0.00

Multiple R	0.686
R Square	0.446
Adjusted R Square	0.445
Standard Error	47.471
Mean Absolute Deviation	36.0

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE0510	0.561	0.084	0.052	2.391	6.662	0.000
PAGE1115	0.212	0.084	0.019	2.140	2.528	0.012
PAGE1619	0.283	0.095	0.021	1.950	2.966	0.003
PAGE2029	0.656	0.077	0.062	2.039	8.577	0.000
PAGE3039	0.233	0.074	0.027	2.814	3.158	0.002
PAGE4049	0.134	0.079	0.014	2.590	1.692	0.091
PAGE5059	-0.505	0.071	-0.060	2.797	-7.074	0.000
PAGE6069	-0.419	0.061	-0.052	2.197	-6.907	0.000
PFTWRKRS	0.342	0.057	0.049	2.584	5.999	0.000
PUNEMPLO	0.458	0.137	0.020	1.390	3.333	0.001
PRETIRED	0.300	0.065	0.033	2.050	4.592	0.000
PSTUDENT	2.879	0.315	0.050	1.165	9.147	0.000
PSEG1	0.649	0.027	0.159	1.718	24.155	0.000
PSEG2	0.281	0.027	0.063	1.479	10.331	0.000
PSEG3	-0.244	0.022	-0.073	1.698	-11.074	0.000
PSEG4	-0.226	0.033	-0.040	1.375	-6.817	0.000
PSEG5	-0.220	0.046	-0.027	1.232	-4.822	0.000
PHHLICS1	0.315	0.026	0.085	1.892	12.323	0.000
PHHLICS2	0.508	0.030	0.159	3.501	16.841	0.000
PHHSTR1	0.600	0.092	0.039	1.393	6.525	0.000
PHHSTR2	-0.340	0.081	-0.025	1.429	-4.198	0.000
PHHSTR3	0.403	0.081	0.032	1.607	4.954	0.000
PHHSTR4	0.568	0.053	0.084	2.454	10.641	0.000
PHHSTR7	0.351	0.052	0.046	1.809	6.782	0.000
PHHSTR9	0.440	0.054	0.050	1.491	8.109	0.000
PHHSTR10	0.166	0.064	0.016	1.544	2.615	0.009
PHHSTR11	-0.267	0.032	-0.059	1.962	-8.296	0.000
PHHSTR12	-0.320	0.039	-0.053	1.592	-8.306	0.000
CARSPP	50.204	1.711	0.256	3.009	29.348	0.000
PLOCACLO	0.574	0.130	0.029	1.695	4.432	0.000
PCITY13	-0.327	0.024	-0.083	1.467	-13.688	0.000
PCITY26	-0.099	0.017	-0.035	1.450	-5.809	0.000
PCITY43	-0.095	0.022	-0.027	1.607	-4.295	0.000
PBSTOP06	0.223	0.029	0.042	1.169	7.656	0.000
PBSTOP13	-0.466	0.060	-0.044	1.309	-7.723	0.000
PBSTOP26	0.942	0.123	0.047	1.480	7.686	0.000
PBSTOP43	-0.287	0.117	-0.015	1.397	-2.453	0.014
PBSFREQ1	0.047	0.023	0.016	2.506	2.003	0.045
PBSFREQ2	-0.027	0.015	-0.011	1.351	-1.814	0.070
PRLY06	-0.124	0.028	-0.027	1.460	-4.406	0.000
PRLY13	-0.084	0.026	-0.020	1.521	-3.299	0.001
PRLY43	-0.116	0.020	-0.035	1.397	-5.837	0.000

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
SETT_LON	-9.610	1.887	-0.041	2.557	-5.092	0.000
SETT_MET	-5.561	1.622	-0.031	3.179	-3.429	0.001
SETT_250	-7.696	1.532	-0.043	2.843	-5.022	0.000
SETT_100	3.552	1.293	0.018	1.740	2.748	0.006
SETT_025	-3.779	1.363	-0.016	1.379	-2.773	0.006
WDENS00	-4.388	1.341	-0.028	2.865	-3.272	0.001
WDENS20	4.844	1.075	0.028	1.479	4.506	0.000
WDENS30	9.203	1.010	0.053	1.345	9.109	0.000
WDENS40	-3.278	1.124	-0.017	1.294	-2.915	0.004
LDENS00	11.984	1.125	0.081	2.296	10.655	0.000
LDENS20	-4.495	1.285	-0.034	3.657	-3.498	0.001
(Constant)	64.616	4.523			14.287	0.000



A5.1.2 Dependent Variable = Distance per person / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	*R^2*	*Adjusted R^2*	*F*	*Significance*
1.	CARSPP	entered	0.31	0.31	9927	0.00
2.	PSEG1	entered	0.34	0.34	5531	0.00
3.	PSEG3	entered	0.34	0.34	3834	0.00
4.	PSEG4	entered	0.35	0.35	2949	0.00
5.	PSEG5	entered	0.35	0.35	2404	0.00
6.	PWORKERS	entered	0.36	0.36	2036	0.00
7.	PSEG2	entered	0.36	0.36	1746	0.00

Multiple R	0.599
R Square	0.358
Adjusted R Square	0.358
Standard Error	51.047
Mean Absolute Deviation	39.2

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	79.526	1.319	0.406	1.547	60.298	0.000
PSEG1	0.538	0.027	0.132	1.494	19.944	0.000
PSEG2	0.059	0.027	0.013	1.242	2.198	0.028
PSEG3	-0.399	0.021	-0.119	1.386	-18.599	0.000
PSEG4	-0.453	0.033	-0.081	1.209	-13.562	0.000
PSEG5	-0.530	0.047	-0.065	1.138	-11.245	0.000
PWORKERS	0.386	0.036	0.061	1.080	10.845	0.000
(Constant)	92.651	2.187			42.366	0.000

A5.1.3 Dependent Variable = Cars per person / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	PHHLICS0	entered	0.62	0.62	35424	0.00
2.	PHHLICS1	entered	0.72	0.72	27726	0.00
3.	PHHLICS2	entered	0.74	0.74	20326	0.00
4.	PSEG1	entered	0.75	0.75	16371	0.00
5.	PLOCACHI	entered	0.76	0.76	13644	0.00
6.	PUNEMPLO	entered	0.76	0.76	11617	0.00
7.	PHHSTR3	entered	0.76	0.76	10174	0.00
8.	PAGE5059	entered	0.76	0.76	9020	0.00
9.	SETT_100	entered	0.77	0.77	8106	0.00
10.	PBSTOP13	entered	0.77	0.77	7347	0.00
11.	PWORKERS	entered	0.77	0.77	6714	0.00
12.	PAGE1619	entered	0.77	0.77	6190	0.00
13.	PHHSTR4	entered	0.77	0.77	5754	0.00
14.	SETT_050	entered	0.77	0.77	5373	0.00
15.	PCITY06	entered	0.78	0.78	5041	0.00
16.	SETT_LON	entered	0.78	0.78	4746	0.00
17.	PRLY06	entered	0.78	0.78	4485	0.00
18.	SETT_025	entered	0.78	0.78	4249	0.00
19.	PRLY26	entered	0.78	0.78	4040	0.00
20.	WDENS40	entered	0.78	0.78	3849	0.00
21.	PRLY43	entered	0.78	0.78	3675	0.00
22.	WDENS00	entered	0.78	0.78	3517	0.00
23.	LDENS00	entered	0.78	0.78	3380	0.00
24.	WDENS20	entered	0.78	0.78	3248	0.00
25.	WDENS10	entered	0.78	0.78	3128	0.00
26.	PHHSTR10	entered	0.78	0.78	3015	0.00
27.	PAGE3039	entered	0.78	0.78	2910	0.00
28.	PHHSTR8	entered	0.78	0.78	2817	0.00
29.	PAGE2029	entered	0.78	0.78	2726	0.00
30.	PSEG2	entered	0.78	0.78	2641	0.00
31.	PAGE0510	entered	0.78	0.78	2559	0.00
32.	PCITY43	entered	0.78	0.78	2481	0.00
33.	PBSFREQ2	entered	0.78	0.78	2408	0.00
34.	PBSFREQ1	entered	0.78	0.78	2340	0.00
35.	PBSTOP06	entered	0.78	0.78	2275	0.00
36.	PSEG3	entered	0.78	0.78	2214	0.00
37.	SETT_250	entered	0.78	0.78	2156	0.00
38.	PRLY13	entered	0.79	0.78	2100	0.00
39.	PCITY13	entered	0.79	0.78	2048	0.00
40.	PSEG5	entered	0.79	0.78	1997	0.00
41.	PAGE4049	entered	0.79	0.78	1950	0.00
42.	PHHSTR5	entered	0.79	0.79	1904	0.00
43.	SETT_MET	entered	0.79	0.79	1860	0.00
44.	LDENS20	entered	0.79	0.79	1819	0.00
45.	PSEG4	entered	0.79	0.79	1780	0.00
46.	PBSTOP26	entered	0.79	0.79	1741	0.00
47.	PHHSTR1	entered	0.79	0.79	1705	0.00

Multiple R	0.886
R Square	0.786
Adjusted R Square	0.785
Standard Error	0.151
Mean Absolute Deviation	0.11

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE0510	-0.001	0.000	-0.016	1.628	-3.996	0.000
PAGE1619	-0.004	0.000	-0.056	1.723	-13.581	0.000
PAGE2029	-0.001	0.000	-0.023	1.707	-5.589	0.000
PAGE3039	-0.001	0.000	-0.025	2.358	-5.133	0.000
PAGE4049	0.001	0.000	0.013	1.920	3.005	0.003
PAGE5059	0.002	0.000	0.050	2.202	10.808	0.000
PUNEMPLO	-0.005	0.000	-0.042	1.362	-11.583	0.000
PSEG1	0.003	0.000	0.126	1.597	31.714	0.000
PSEG2	0.001	0.000	0.023	1.454	6.039	0.000
PSEG3	0.000	0.000	0.011	1.663	2.721	0.007
PSEG4	0.000	0.000	-0.010	1.353	-2.728	0.006
PSEG5	0.000	0.000	-0.011	1.221	-3.249	0.001
PHHLICS0	-0.018	0.000	-1.009	8.976	-107.543	0.000
PHHLICS1	-0.010	0.000	-0.518	6.891	-62.984	0.000
PHHLICS2	-0.006	0.000	-0.345	9.704	-35.337	0.000
PHHSTR1	-0.001	0.000	-0.009	1.261	-2.468	0.014
PHHSTR3	-0.003	0.000	-0.052	1.495	-13.697	0.000
PHHSTR4	-0.002	0.000	-0.052	1.634	-12.946	0.000
PHHSTR5	0.000	0.000	0.011	1.543	2.904	0.004
PHHSTR8	0.001	0.000	0.034	1.536	8.680	0.000
PHHSTR10	0.001	0.000	0.028	1.299	7.934	0.000
PWORKERS	0.002	0.000	0.057	2.228	12.163	0.000
PLOCACHI	-0.001	0.000	-0.067	1.604	-16.882	0.000
PCITY06	-0.001	0.000	-0.027	1.584	-6.768	0.000
PCITY13	0.000	0.000	0.016	1.659	3.932	0.000
PCITY43	0.000	0.000	-0.012	1.644	-3.015	0.003
PBSTOP06	0.000	0.000	0.016	1.194	4.698	0.000
PBSTOP13	0.002	0.000	0.031	1.280	8.650	0.000
PBSTOP26	-0.001	0.000	-0.009	1.409	-2.520	0.012
PBSFREQ1	0.000	0.000	0.027	2.425	5.543	0.000
PBSFREQ2	0.000	0.000	0.021	1.358	5.762	0.000
PRLY06	0.000	0.000	-0.017	1.464	-4.528	0.000
PRLY13	0.000	0.000	-0.014	1.600	-3.640	0.000
PRLY26	0.001	0.000	0.039	1.263	11.053	0.000
PRLY43	0.000	0.000	0.028	1.376	7.603	0.000
SETT_LON	0.061	0.006	0.051	2.877	9.670	0.000
SETT_MET	0.024	0.006	0.026	3.716	4.366	0.000
SETT_250	0.031	0.005	0.034	3.435	5.838	0.000
SETT_100	-0.029	0.005	-0.029	2.345	-6.081	0.000
SETT_050	-0.036	0.005	-0.029	1.652	-7.142	0.000
SETT_025	-0.032	0.005	-0.027	1.630	-6.748	0.000
WDENS00	0.064	0.005	0.080	4.038	12.746	0.000
WDENS10	0.032	0.004	0.034	2.006	7.669	0.000
WDENS20	0.033	0.004	0.037	1.730	9.054	0.000
WDENS40	-0.016	0.004	-0.016	1.243	-4.481	0.000
LDENS00	-0.035	0.004	-0.046	2.536	-9.258	0.000
LDENS20	-0.015	0.004	-0.022	3.719	-3.703	0.000
(Constant)	1.662	0.019			86.503	0.000

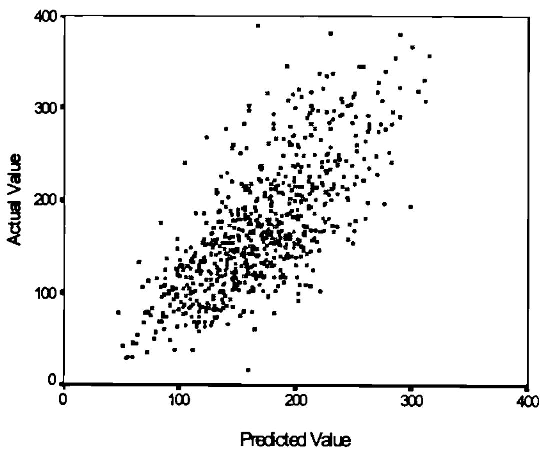
A5.2 Regression Analyses with Data from the 1985/86 National Travel Survey

A5.2.1 Dependent Variable = Distance per person / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.45	0.45	19974	0.00
2.	PSEG1	entered	0.47	0.47	10824	0.00
3.	WDENS00	entered	0.49	0.49	7706	0.00
4.	PWORKERS	entered	0.50	0.50	6106	0.00
5.	PHHSTR10	entered	0.51	0.51	5000	0.00
6.	PSEG2	entered	0.51	0.51	4270	0.00
7.	PAGE0510	entered	0.52	0.52	3734	0.00
8.	SETT_LON	entered	0.52	0.52	3322	0.00
9.	PBSFREQ1	entered	0.53	0.53	2989	0.00
10.	SETT_100	entered	0.53	0.53	2711	0.00
11.	PHHLICS1	entered	0.53	0.53	2484	0.00
12.	PSTUDENT	entered	0.54	0.54	2289	0.00
13.	WDENS40	entered	0.54	0.54	2124	0.00
14.	PHHSTR4	entered	0.54	0.54	1981	0.00
15.	PHHSTR3	entered	0.54	0.54	1857	0.00
16.	LDENS10	entered	0.54	0.54	1747	0.00
17.	LDENS05	entered	0.55	0.55	1650	0.00
18.	PRLY13	entered	0.55	0.55	1564	0.00
19.	PCITY13	entered	0.55	0.55	1488	0.00
20.	PAGE5059	entered	0.55	0.55	1418	0.00
21.	PHHLICS2	entered	0.55	0.55	1355	0.00
22.	PSEG4	entered	0.55	0.55	1298	0.00
23.	PRLY43	entered	0.55	0.55	1245	0.00
24.	PCITY06	entered	0.55	0.55	1196	0.00
25.	PLOCACHI	entered	0.55	0.55	1152	0.00
26.	PBSTOP13	entered	0.55	0.55	1111	0.00
27.	PAGE4049	entered	0.56	0.55	1072	0.00
28.	PAGE2029	entered	0.56	0.56	1036	0.00
29.	SETT_003	entered	0.56	0.56	1003	0.00
30.	SETT_025	entered	0.56	0.56	971	0.00
31.	PHHSTR1	entered	0.56	0.56	941	0.00
32.	PBSTOP06	entered	0.56	0.56	912	0.00
33.	PAGE6069	entered	0.56	0.56	886	0.00
34.	PCITY43	entered	0.56	0.56	860	0.00
35.	PCITY26	entered	0.56	0.56	837	0.00
36.	PFTWRKRS	entered	0.56	0.56	814	0.00
37.	PBSTOP26	entered	0.56	0.56	793	0.00
38.	PAGE3039	entered	0.56	0.56	772	0.00
39.	PBSTOP43	entered	0.56	0.56	753	0.00
40.	SETT_050	entered	0.56	0.56	734	0.00
41.	PRLY26	entered	0.56	0.56	716	0.00
42.	PHHSTR9	entered	0.56	0.56	699	0.00

Multiple R	0.739
R Square	0.547
Adjusted R Square	0.546
Standard Error	45.273
Mean Absolute Deviation	35.1

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE0510	-0.576	0.074	-0.041	1.486	-7.778	0.000
PAGE2029	0.421	0.066	0.039	1.988	6.409	0.000
PAGE3039	0.174	0.064	0.018	2.326	2.718	0.007
PAGE4049	0.472	0.066	0.046	2.178	7.198	0.000
PAGE5059	0.534	0.061	0.055	2.119	8.699	0.000
PAGE6069	0.213	0.052	0.022	1.638	4.061	0.000
PFTWRKRS	-0.272	0.074	-0.039	6.010	-3.683	0.000
PSTUDENT	0.711	0.094	0.036	1.229	7.527	0.000
PSEG1	0.806	0.023	0.205	1.860	34.860	0.000
PSEG2	0.565	0.026	0.111	1.359	22.071	0.000
PSEG4	0.210	0.031	0.035	1.451	6.772	0.000
PHHLICS1	-0.064	0.025	-0.015	1.739	-2.561	0.010
PHHLICS2	0.237	0.027	0.069	3.214	8.889	0.000
PHHSTR1	0.223	0.073	0.016	1.430	3.060	0.002
PHHSTR3	0.460	0.065	0.038	1.557	7.042	0.000
PHHSTR4	0.147	0.040	0.019	1.480	3.645	0.000
PHHSTR9	-0.086	0.042	-0.009	1.169	-2.031	0.042
PHHSTR10	-0.786	0.045	-0.085	1.283	-17.364	0.000
CARSPP	70.412	1.334	0.404	3.150	52.797	0.000
PWORKERS	0.828	0.069	0.129	6.124	12.045	0.000
PLOCACHI	-0.144	0.018	-0.047	1.789	-8.142	0.000
PCITY06	0.101	0.023	0.025	1.682	4.379	0.000
PCITY13	-0.220	0.022	-0.053	1.521	-9.975	0.000
PCITY26	-0.061	0.017	-0.019	1.511	-3.639	0.000
PCITY43	-0.090	0.022	-0.023	1.783	-4.060	0.000
PBSTOP06	-0.076	0.021	-0.017	1.106	-3.691	0.000
PBSTOP13	-0.232	0.032	-0.035	1.225	-7.354	0.000
PBSTOP26	0.190	0.064	0.015	1.301	2.977	0.003
PBSTOP43	0.198	0.087	0.011	1.228	2.276	0.023
PBSFREQ1	0.206	0.019	0.074	2.348	11.144	0.000
PRLY13	0.203	0.020	0.053	1.517	10.019	0.000
PRLY26	-0.030	0.014	-0.010	1.310	-2.106	0.035
PRLY43	0.150	0.020	0.040	1.467	7.604	0.000
SETT_LON	-8.264	1.139	-0.041	1.730	-7.252	0.000
SETT_100	9.179	1.076	0.042	1.291	8.530	0.000
SETT_050	2.397	1.071	0.011	1.272	2.239	0.025
SETT_025	-3.965	1.343	-0.014	1.233	-2.952	0.003
SETT_003	4.823	0.895	0.029	1.586	5.389	0.000
WDENS00	13.754	0.933	0.094	2.195	14.745	0.000
WDENS40	-7.147	1.087	-0.030	1.110	-6.574	0.000
LDENS05	4.657	0.935	0.023	1.151	4.981	0.000
LDENS10	7.221	1.095	0.030	1.135	6.594	0.000
(Constant)	16.051	3.331			4.819	0.000



A5.2.2 Dependent Variable = Distance per person / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.45	0.45	119974	0.00
2.	PSEG1	entered	0.47	0.47	10824	0.00
3.	PWORKERS	entered	0.48	0.48	7539	0.00
4.	PSEG3	entered	0.49	0.49	5810	0.00
5.	PSEG4	entered	0.49	0.49	4663	0.00
6.	PSEG5	entered	0.49	0.49	3897	0.00
7.	PSEG2	entered	0.49	0.49	3343	0.00

Multiple R	0.700
R Square	0.490
Adjusted R Square	0.490
Standard Error	48.007
Mean Absolute Deviation	37.2

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	86.960	1.125	0.499	1.995	77.268	0.000
PSEG1	0.356	0.032	0.091	3.188	11.113	0.000
PSEG2	-0.102	0.034	-0.020	2.175	-2.981	0.003
PSEG3	-0.534	0.032	-0.130	2.909	-16.608	0.000
PSEG4	-0.276	0.038	-0.046	1.964	-7.215	0.000
PSEG5	-0.361	0.054	-0.036	1.418	-6.656	0.000
PWORKERS	0.727	0.033	0.113	1.280	21.836	0.000
(Constant)	65.538	3.053			21.466	0.000

A5.2.3 Dependent Variable = Cars per person / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	PHHLICS0	entered	0.57	0.57	31910	0.00
2.	PHHLICS1	entered	0.72	0.72	31969	0.00
3.	PHHLICS2	entered	0.76	0.76	25317	0.00
4.	PSEG1	entered	0.77	0.77	20793	0.00
5.	PBSFREQ1	entered	0.79	0.79	17998	0.00
6.	PRLY06	entered	0.79	0.79	15299	0.00
7.	PWORKERS	entered	0.79	0.79	13425	0.00
8.	PBSTOP06	entered	0.80	0.80	11911	0.00
9.	PCITY13	entered	0.80	0.80	10727	0.00
10.	PLOCACHI	entered	0.80	0.80	9758	0.00
11.	SETT_LON	entered	0.80	0.80	8988	0.00
12.	PAGE1115	entered	0.80	0.80	8298	0.00
13.	PAGE5059	entered	0.80	0.80	7728	0.00
14.	PSEG2	entered	0.81	0.81	7237	0.00
15.	PSTUDENT	entered	0.81	0.81	6811	0.00
16.	PBSTOP26	entered	0.81	0.81	6425	0.00
17.	PHHSTR6	entered	0.81	0.81	6083	0.00
18.	PCITY26	entered	0.81	0.81	5775	0.00
19.	PUNEMPLO	entered	0.81	0.81	5496	0.00
20.	PCITY43	entered	0.81	0.81	5239	0.00
21.	PHHSTR11	entered	0.81	0.81	5007	0.00
22.	PHHSTR2	entered	0.81	0.81	4795	0.00
23.	PSEG3	entered	0.81	0.81	4602	0.00
24.	PAGE6069	entered	0.81	0.81	4425	0.00
25.	PRETIRED	entered	0.81	0.81	4266	0.00
26.	PSEG5	entered	0.81	0.81	4114	0.00
27.	PHHSTR9	entered	0.82	0.81	3973	0.00
28.	PHHSTR3	entered	0.82	0.82	3839	0.00
29.	WDENS00	entered	0.82	0.82	3715	0.00
30.	SETT_MET	entered	0.82	0.82	3600	0.00
31.	LDENS10	entered	0.82	0.82	3493	0.00
32.	PRLY13	entered	0.82	0.82	3389	0.00
33.	PHHSTR5	entered	0.82	0.82	3291	0.00
34.	PHHSTR7	entered	0.82	0.82	3200	0.00
35.	PSEG4	entered	0.82	0.82	3114	0.00
36.	PSEG2	removed	0.82	0.82	3206	0.00
37.	PHHSTR10	entered	0.82	0.82	3118	0.00
38.	PHHSTR8	entered	0.82	0.82	3035	0.00
39.	PHHSTR1	entered	0.82	0.82	2957	0.00
40.	PHHSTR4	entered	0.82	0.82	2882	0.00
41.	PHHSTR3	removed	0.82	0.82	2959	0.00
42.	PHHSTR12	entered	0.82	0.82	2890	0.00
43.	PHHSTR3	entered	0.82	0.82	2820	0.00
44.	PAGE1619	entered	0.82	0.82	2753	0.00
45.	SETT_003	entered	0.82	0.82	2687	0.00
46.	PAGE3039	entered	0.82	0.82	2626	0.00
47.	PAGE4049	entered	0.82	0.82	2571	0.00
48.	PWORKERS	removed	0.82	0.82	2632	0.00
49.	WDENS10	entered	0.82	0.82	2573	0.00
50.	SETT_250	entered	0.82	0.82	2516	0.00
51.	SETT_100	entered	0.82	0.82	2462	0.00
52.	SETT_050	entered	0.82	0.82	2415	0.00
53.	SETT_025	entered	0.82	0.82	2366	0.00
54.	SETT_LON	removed	0.82	0.82	2418	0.00
55.	LDENS05	entered	0.82	0.82	2367	0.00
56.	LDENS20	entered	0.82	0.82	2320	0.00
57.	PBSTOP13	entered	0.82	0.82	2273	0.00
58.	PAGE2029	entered	0.82	0.82	2229	0.00
59.	WDENS40	entered	0.82	0.82	2186	0.00

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
60.	PRLY43	entered	0.82	0.82	2144	0.00
61.	PRLY26	entered	0.82	0.82	2104	0.00

Multiple R	0.961
R Square	0.821
Adjusted R Square	0.821
Standard Error	0.163
Mean Absolute Deviation	0.13

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE1115	0.004	0.000	0.053	1.751	14.818	0.000
PAGE1619	-0.001	0.000	-0.010	2.420	-2.420	0.016
PAGE2029	0.001	0.000	0.012	2.401	2.807	0.005
PAGE3039	0.002	0.000	0.034	2.604	7.713	0.000
PAGE4049	0.002	0.000	0.026	2.366	6.275	0.000
PAGE5059	0.003	0.000	0.059	2.589	13.454	0.000
PAGE6069	0.003	0.000	0.052	2.185	12.878	0.000
PUNEMPLO	-0.005	0.000	-0.056	1.579	-16.382	0.000
PRETIRED	-0.001	0.000	-0.028	3.435	-5.607	0.000
PSTUDENT	-0.006	0.000	-0.051	1.503	-15.428	0.000
PSEG1	0.003	0.000	0.122	2.392	29.171	0.000
PSEG3	-0.002	0.000	-0.069	1.978	-18.003	0.000
PSEG4	-0.001	0.000	-0.032	1.660	-9.109	0.000
PSEG5	-0.002	0.000	-0.039	1.365	-12.253	0.000
PHHLICS0	-0.021	0.000	-0.890	7.484	-119.856	0.000
PHHLICS1	-0.014	0.000	-0.567	5.418	-89.813	0.000
PHHLICS2	-0.009	0.000	-0.435	8.291	-55.644	0.000
PHHSTR1	-0.004	0.000	-0.052	2.885	-11.347	0.000
PHHSTR2	-0.005	0.000	-0.059	2.846	-12.907	0.000
PHHSTR3	-0.002	0.000	-0.022	3.310	-4.480	0.000
PHHSTR4	-0.003	0.000	-0.074	6.196	-10.995	0.000
PHHSTR5	-0.004	0.000	-0.086	6.667	-12.309	0.000
PHHSTR6	-0.005	0.000	-0.125	7.125	-17.194	0.000
PHHSTR7	-0.004	0.000	-0.088	5.427	-13.999	0.000
PHHSTR8	-0.004	0.000	-0.125	14.405	-12.172	0.000
PHHSTR9	-0.004	0.000	-0.083	4.425	-14.469	0.000
PHHSTR10	-0.004	0.000	-0.067	3.822	-12.580	0.000
PHHSTR11	-0.005	0.000	-0.137	11.021	-15.232	0.000
PHHSTR12	-0.003	0.000	-0.060	5.065	-9.850	0.000
PLOCACHI	-0.001	0.000	-0.064	1.677	-18.153	0.000
PCITY13	-0.001	0.000	-0.047	1.550	-13.849	0.000
PCITY26	-0.001	0.000	-0.033	1.457	-10.043	0.000
PCITY43	-0.001	0.000	-0.027	1.602	-7.964	0.000
PBSTOP06	0.001	0.000	0.055	1.129	19.010	0.000
PBSTOP13	0.000	0.000	-0.009	1.226	-3.094	0.002
PBSTOP26	0.002	0.000	0.032	1.309	10.383	0.000
PBSFREQ1	0.001	0.000	0.057	2.335	13.699	0.000
PRLY06	-0.002	0.000	-0.061	1.702	-17.143	0.000
PRLY13	-0.001	0.000	-0.030	1.688	-8.426	0.000
PRLY26	0.000	0.000	0.008	1.354	2.444	0.015
PRLY43	0.000	0.000	-0.010	1.541	-2.965	0.003
SETT_MET	-0.075	0.004	-0.068	2.199	-17.015	0.000
SETT_250	-0.059	0.004	-0.051	1.880	-13.757	0.000
SETT_100	-0.056	0.005	-0.044	1.793	-12.133	0.000
SETT_050	-0.055	0.005	-0.043	1.738	-12.124	0.000
SETT_025	-0.036	0.005	-0.022	1.503	-6.645	0.000
SETT_003	-0.048	0.004	-0.050	1.937	-13.371	0.000
WDENS00	-0.036	0.004	-0.043	2.541	-9.990	0.000
WDENS10	-0.017	0.004	-0.014	1.299	-4.538	0.000
WDENS40	-0.011	0.004	-0.008	1.163	-2.785	0.005
LDENS05	0.014	0.003	0.012	1.221	3.919	0.000
LDENS10	0.038	0.004	0.027	1.206	9.224	0.000
LDENS20	0.017	0.005	0.011	1.182	3.584	0.000
(Constant)	2.642	0.032			81.855	0.000

A5.3 Regression Analyses with Data from the 1989/91 National Travel Survey

A5.3.1 Dependent Variable = Distance per person / Independent Variables = Land Use and Socio-Economic Variables

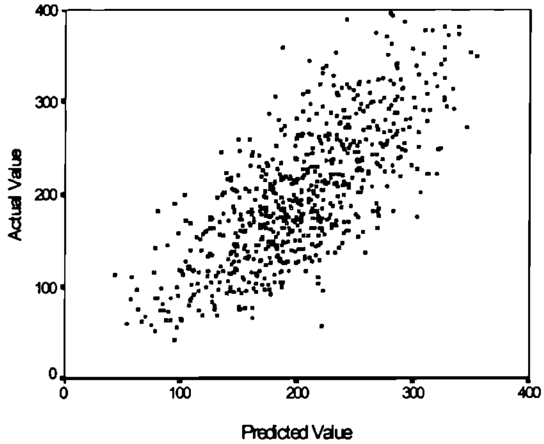
Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.40	0.40	17053	0.00
2.	PSEG1	entered	0.45	0.45	10130	0.00
3.	WDENS00	entered	0.48	0.48	7797	0.00
4.	PFTWRKRS	entered	0.50	0.50	6218	0.00
5.	PHHLICS2	entered	0.51	0.51	5210	0.00
6.	LDENS00	entered	0.52	0.52	4507	0.00
7.	PSEG4	entered	0.52	0.52	3948	0.00
8.	PHHSTR3	entered	0.53	0.53	3536	0.00
9.	PAGE4049	entered	0.54	0.54	3223	0.00
10.	PCITY26	entered	0.54	0.54	2938	0.00
11.	PLOCACHI	entered	0.54	0.54	2713	0.00
12.	PCITY43	entered	0.55	0.55	2508	0.00
13.	SETT_100	entered	0.55	0.55	2334	0.00
14.	PHHSTR6	entered	0.55	0.55	2185	0.00
15.	PUNEMPLO	entered	0.55	0.55	2055	0.00
16.	PSTUDENT	entered	0.55	0.55	1939	0.00
17.	PAGE1619	entered	0.56	0.56	1850	0.00
18.	PCITY13	entered	0.56	0.56	1761	0.00
19.	SETT_050	entered	0.56	0.56	1676	0.00
20.	PHHSTR10	entered	0.56	0.56	1598	0.00
21.	SETT_LON	entered	0.56	0.56	1528	0.00
22.	PRLY13	entered	0.56	0.56	1427	0.00
23.	PHHSTR7	entered	0.56	0.56	1409	0.00
24.	PHHSTR12	entered	0.56	0.56	1356	0.00
25.	PLOCACLO	entered	0.57	0.57	1308	0.00
26.	WDENS30	entered	0.57	0.57	1262	0.00
27.	SETT_250	entered	0.57	0.57	1219	0.00
28.	SETT_025	entered	0.57	0.57	1180	0.00
29.	PHHSTR11	entered	0.57	0.57	1144	0.00
30.	PBSTOP26	entered	0.57	0.57	1108	0.00
31.	PAGE1115	entered	0.57	0.57	1075	0.00
32.	PAGE2029	entered	0.57	0.57	1044	0.00
33.	SETT_003	entered	0.57	0.57	1014	0.00
34.	SETT_050	removed	0.57	0.57	1046	0.00
35.	SETT_MET	entered	0.57	0.57	1018	0.00
36.	SETT_100	removed	0.57	0.57	1050	0.00
37.	SETT_050	entered	0.57	0.57	1020	0.00
38.	PHHLICS1	entered	0.57	0.57	992	0.00
39.	PAGE3039	entered	0.57	0.57	965	0.00
40.	LDENS10	entered	0.57	0.57	940	0.00
41.	SETT_100	entered	0.57	0.57	916	0.00
42.	LDENS05	entered	0.58	0.57	893	0.00
43.	PRLY43	entered	0.58	0.57	871	0.00
44.	PSEG5	entered	0.58	0.58	850	0.00
45.	PWORKERS	entered	0.58	0.58	831	0.00
46.	LDENS15	entered	0.58	0.58	812	0.00
47.	LDENS20	entered	0.58	0.58	794	0.00
48.	PSEG3	entered	0.58	0.58	776	0.00
49.	PBSFREQ1	entered	0.58	0.58	760	0.00
50.	PAGE0510	entered	0.58	0.58	744	0.00
51.	PRETIRED	entered	0.58	0.58	729	0.00
52.	PAGE5059	entered	0.58	0.58	714	0.00
53.	PAGE6069	entered	0.58	0.58	700	0.00

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
54.	PAGE0004	entered	0.58	0.58	687	0.00
55.	PAGE1115	removed	0.58	0.58	700	0.00
56.	PWORKERS	removed	0.58	0.58	715	0.00
57.	PAGE3039	removed	0.58	0.58	730	0.00
58.	WDENS40	entered	0.58	0.58	715	0.00
59.	PBSTOP13	entered	0.58	0.58	701	0.00
60.	PHHSTR2	entered	0.58	0.58	687	0.00
61.	PHHSTR5	entered	0.58	0.58	674	0.00

Multiple R	0.761
R Square	0.578
Adjusted R Square	0.578
Standard Error	51.341
Mean Absolute Deviation	40.1

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE0004	-0.657	0.095	-0.041	2.091	-6.943	0.000
PAGE0510	-0.933	0.097	-0.060	2.366	-9.580	0.000
PAGE1619	-1.197	0.117	-0.059	1.938	-10.246	0.000
PAGE2029	0.250	0.075	0.020	2.125	3.350	0.001
PAGE4049	0.584	0.062	0.052	1.798	9.414	0.000
PAGE5059	-0.456	0.061	-0.038	1.532	-7.511	0.000
PAGE6069	-0.359	0.064	-0.032	1.972	-5.639	0.000
PFTWRKRS	0.811	0.057	0.103	3.135	14.160	0.000
PUNEMPLO	1.110	0.116	0.050	1.587	9.603	0.000
PRETIRED	-0.369	0.067	-0.043	3.662	-5.469	0.000
PSTUDENT	1.077	0.116	0.055	2.052	9.320	0.000
PSEG1	0.795	0.028	0.183	2.473	28.341	0.000
PSEG3	-0.095	0.029	-0.019	1.936	-3.329	0.001
PSEG4	-0.485	0.037	-0.066	1.488	-13.098	0.000
PSEG5	-0.361	0.062	-0.028	1.389	-5.793	0.000
PHHLICS1	0.100	0.032	0.018	2.035	3.146	0.002
PHHLICS2	0.448	0.031	0.110	3.385	14.619	0.000
PHHSTR2	-0.288	0.095	-0.016	1.728	-3.029	0.003
PHHSTR3	0.604	0.080	0.040	1.679	7.558	0.000
PHHSTR5	-0.140	0.064	-0.014	2.351	-2.184	0.029
PHHSTR6	0.119	0.039	0.014	1.308	3.033	0.002
PHHSTR7	-0.378	0.044	-0.042	1.396	-8.623	0.000
PHHSTR10	-0.609	0.056	-0.056	1.569	-10.888	0.000
PHHSTR11	-0.246	0.036	-0.035	1.622	-6.754	0.000
PHHSTR12	-0.492	0.050	-0.047	1.353	-9.746	0.000
CARSPP	63.508	1.432	0.318	3.065	44.339	0.000
PLOCACHI	-0.280	0.018	-0.077	1.511	-15.230	0.000
PLOCACLO	0.614	0.099	0.033	1.697	6.223	0.000
PCITY13	-0.198	0.024	-0.042	1.542	-8.268	0.000
PCITY26	-0.208	0.018	-0.058	1.439	-11.859	0.000
PCITY43	-0.234	0.024	-0.052	1.707	-9.764	0.000
PBSTOP13	-0.108	0.040	-0.013	1.260	-2.724	0.007
PBSTOP26	-0.488	0.076	-0.031	1.375	-6.419	0.000
PBSFREQ1	-0.081	0.025	-0.022	2.891	-3.211	0.001
PRLY13	0.283	0.025	0.060	1.601	11.514	0.000
PRLY43	0.077	0.021	0.018	1.518	3.654	0.000
SETT_LON	-43.344	2.221	-0.177	4.910	-19.516	0.000
SETT_MET	-25.523	2.107	-0.114	5.293	-12.112	0.000
SETT_250	-32.683	2.022	-0.141	4.516	-16.162	0.000
SETT_100	-12.447	2.052	-0.049	3.871	-6.066	0.000
SETT_050	-15.942	1.968	-0.064	3.664	-8.099	0.000
SETT_025	-29.002	2.042	-0.105	3.217	-14.206	0.000
SETT_003	-17.544	1.582	-0.085	3.531	-11.092	0.000
WDENS00	13.655	1.086	0.079	2.366	12.572	0.000
WDENS30	-5.514	0.991	-0.025	1.213	-5.567	0.000
WDENS40	4.255	1.266	0.015	1.202	3.361	0.001
LDENS00	4.843	1.368	0.030	4.302	3.540	0.000
LDENS05	-8.664	1.398	-0.036	1.985	-6.196	0.000

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
LDENS10	-9.536	1.390	-0.035	1.507	-6.859	0.000
LDENS15	-6.420	1.573	-0.020	1.389	-4.081	0.000
LDENS20	-6.087	1.593	-0.018	1.297	-3.820	0.000
(Constant)	135.018	6.123			22.050	0.000



A5.3.2 Dependent Variable = Distance per person / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	Entered	0.40	0.40	17053	0.00
2.	PSEG1	entered	0.45	0.45	10130	0.00
3.	PWORKERS	entered	0.46	0.46	7120	0.00
4.	PSEG4	entered	0.47	0.47	5540	0.00
5.	PSEG3	entered	0.47	0.47	4451	0.00
6.	PSEG2	entered	0.47	0.47	3729	0.00
7.	PSEG5	entered	0.47	0.47	3237	0.00

Multiple R	0.689
R Square	0.474
Adjusted R Square	0.474
Standard Error	57.273
Mean Absolute Deviation	44.6

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	83.539	1.211	0.419	1.760	68.994	0.000
PSEG1	0.384	0.038	0.088	3.602	10.171	0.000
PSEG2	-0.524	0.042	-0.083	2.121	-12.524	0.000
PSEG3	-0.544	0.038	-0.108	2.747	-14.298	0.000
PSEG4	-1.214	0.047	-0.164	1.923	-25.850	0.000
PSEG5	-0.875	0.071	-0.068	1.454	-12.307	0.000
PWORKERS	0.922	0.037	0.127	1.276	24.643	0.000
(Constant)	100.163	3.726			26.883	0.000

A5.3.3 Dependent Variable = Cars per person / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	PHHLICS0	entered	0.56	0.56	32538	0.00
2.	PHHLICS1	entered	0.69	0.69	28241	0.00
3.	PHHLICS2	entered	0.73	0.73	22238	0.00
4.	PBSFREQ1	entered	0.74	0.74	17705	0.00
5.	PSEG1	entered	0.75	0.75	14861	0.00
6.	PCITY13	entered	0.75	0.75	12771	0.00
7.	PBSTOP13	entered	0.76	0.76	11170	0.00
8.	PSTUDENT	entered	0.76	0.76	9923	0.00
9.	PHHSTR10	entered	0.76	0.76	9024	0.00
10.	PAGE4049	entered	0.77	0.77	8226	0.00
11.	PSEG3	entered	0.77	0.77	7576	0.00
12.	PRLY13	entered	0.77	0.77	7028	0.00
13.	PCITY43	entered	0.77	0.77	6572	0.00
14.	PCITY06	entered	0.78	0.78	6207	0.00
15.	PAGE5059	entered	0.78	0.78	5849	0.00
16.	PAGE3039	entered	0.78	0.78	5546	0.00
17.	PHHSTR1	entered	0.78	0.78	5281	0.00
18.	SETT_MET	entered	0.78	0.78	5039	0.00
19.	PSEG2	entered	0.79	0.79	4809	0.00
20.	PSEG5	entered	0.79	0.79	4612	0.00
21.	PSEG4	entered	0.79	0.79	4431	0.00
22.	PLOCACLO	entered	0.79	0.79	4273	0.00
23.	PUNEMPLO	entered	0.79	0.79	4114	0.00
24.	PHHSTR4	entered	0.79	0.79	3970	0.00
25.	PAGE0510	entered	0.79	0.79	3834	0.00
26.	SETT_250	entered	0.79	0.79	3703	0.00
27.	PLOCACHI	entered	0.79	0.79	3579	0.00
28.	PHHSTR6	entered	0.79	0.79	3461	0.00
29.	PHHSTR12	entered	0.79	0.79	3351	0.00
30.	LDENS15	entered	0.80	0.80	3249	0.00
31.	LDENS20	entered	0.80	0.80	3150	0.00
32.	PRLY06	entered	0.80	0.80	3058	0.00
33.	SETT_025	entered	0.80	0.80	2971	0.00
34.	PBSTOP43	entered	0.80	0.80	2889	0.00
35.	PRETIRED	entered	0.80	0.80	2812	0.00
36.	PCITY26	entered	0.80	0.80	2739	0.00
37.	SETT_050	entered	0.80	0.80	2667	0.00
38.	PAGE6069	entered	0.80	0.80	2599	0.00
39.	WDENS40	entered	0.80	0.80	2534	0.00
40.	PBSFREQ2	entered	0.80	0.80	2472	0.00
41.	WDENS30	entered	0.80	0.80	2414	0.00
42.	WDENS10	entered	0.80	0.80	2359	0.00
43.	LDENS10	entered	0.80	0.80	2305	0.00
44.	PHHSTR5	entered	0.80	0.80	2254	0.00
45.	PHHSTR2	entered	0.80	0.80	2205	0.00
46.	SETT_LON	entered	0.80	0.80	2158	0.00
47.	PRLY43	entered	0.80	0.80	2113	0.00
48.	PHHSTR7	entered	0.80	0.80	2069	0.00
49.	PAGE1115	entered	0.80	0.80	2027	0.00
50.	PAGE0004	entered	0.80	0.80	1987	0.00
51.	PWORKERS	entered	0.80	0.80	1949	0.00
52.	PHHSTR11	entered	0.80	0.80	1912	0.00
53.	PHHSTR8	entered	0.80	0.80	1876	0.00
54.	PAGE2029	entered	0.80	0.80	1842	0.00

Multiple R	0.894
R Square	0.799
Adjusted R Square	0.798
Standard Error	0.178
Mean Absolute Deviation	0.14

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE0004	-0.003	0.001	-0.034	6.642	-4.617	0.000
PAGE0510	-0.006	0.001	-0.077	6.847	-10.410	0.000
PAGE1115	-0.003	0.001	-0.035	4.890	-5.636	0.000
PAGE2029	-0.001	0.000	-0.009	2.415	-1.986	0.047
PAGE3039	0.005	0.000	0.079	2.855	16.534	0.000
PAGE4049	0.005	0.000	0.082	2.930	16.900	0.000
PAGE5059	0.005	0.000	0.082	2.616	17.824	0.000
PAGE6069	0.001	0.000	0.016	2.367	3.722	0.000
PUNEMPLO	-0.006	0.000	-0.056	2.012	-13.878	0.000
PRETIRED	-0.001	0.000	-0.029	5.212	-4.417	0.000
PSTUDENT	-0.006	0.000	-0.061	2.129	-14.796	0.000
PSEG1	-0.001	0.000	-0.028	4.557	-4.649	0.000
PSEG2	-0.003	0.000	-0.105	2.666	-22.623	0.000
PSEG3	-0.004	0.000	-0.162	3.368	-31.237	0.000
PSEG4	-0.002	0.000	-0.065	2.333	-15.020	0.000
PSEG5	-0.005	0.000	-0.073	1.672	-19.879	0.000
PHHLICS0	-0.020	0.000	-0.725	5.552	-108.555	0.000
PHHLICS1	-0.012	0.000	-0.456	4.309	-77.580	0.000
PHHLICS2	-0.007	0.000	-0.331	6.989	-44.233	0.000
PHHSTR1	-0.005	0.000	-0.063	1.984	-15.797	0.000
PHHSTR2	-0.002	0.000	-0.023	2.116	-5.548	0.000
PHHSTR4	-0.003	0.000	-0.060	3.328	-11.683	0.000
PHHSTR5	-0.002	0.000	-0.032	3.540	-5.967	0.000
PHHSTR6	0.001	0.000	0.028	2.981	5.629	0.000
PHHSTR7	-0.001	0.000	-0.016	2.506	-3.526	0.000
PHHSTR8	0.001	0.000	0.016	6.474	2.195	0.028
PHHSTR10	0.003	0.000	0.055	2.031	13.678	0.000
PHHSTR11	0.001	0.000	0.023	6.779	3.076	0.002
PHHSTR12	0.001	0.000	0.024	2.004	6.015	0.000
PWORKERS	-0.001	0.000	-0.018	5.752	-2.667	0.008
PLOCACHI	-0.001	0.000	-0.033	1.715	-9.005	0.000
PLOCACLO	-0.006	0.000	-0.064	1.728	-17.280	0.000
PCITY06	-0.001	0.000	-0.045	1.694	-12.258	0.000
PCITY13	-0.002	0.000	-0.068	1.483	-19.603	0.000
PCITY26	0.000	0.000	-0.023	1.423	-6.825	0.000
PCITY43	-0.002	0.000	-0.076	1.792	-20.079	0.000
PBSTOP13	0.003	0.000	0.062	1.237	19.580	0.000
PBSTOP43	0.004	0.001	0.020	1.209	6.482	0.000
PBSFREQ1	0.001	0.000	0.042	2.746	8.873	0.000
PBSFREQ2	0.000	0.000	-0.017	1.472	-4.807	0.000
PRLY06	-0.001	0.000	-0.023	1.698	-6.142	0.000
PRLY13	-0.001	0.000	-0.044	1.686	-12.030	0.000
PRLY43	0.000	0.000	0.007	1.564	2.095	0.036
SETT_LON	0.013	0.005	0.011	1.803	2.826	0.005
SETT_MET	-0.066	0.004	-0.059	1.695	-16.012	0.000
SETT_250	-0.026	0.004	-0.022	1.472	-6.510	0.000
SETT_050	-0.014	0.004	-0.012	1.414	-3.416	0.001
SETT_025	0.026	0.005	0.019	1.379	5.654	0.000
WDENS10	0.013	0.004	0.011	1.400	3.184	0.002
WDENS20	-0.012	0.004	-0.011	1.327	-3.326	0.001
WDENS30	0.018	0.004	0.017	1.354	5.073	0.000
WDENS40	0.027	0.004	0.019	1.260	5.984	0.000
LDENS10	0.016	0.004	0.012	1.192	3.826	0.000
LDENS15	0.048	0.005	0.030	1.131	9.826	0.000
(Constant)	2.507	0.033			75.720	0.000

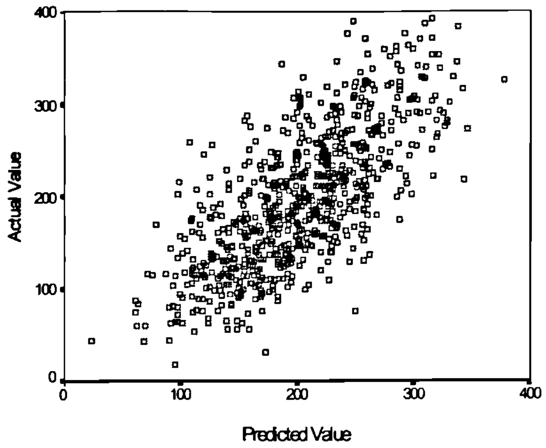
A5.4 REGRESSION ANALYSES WITH DATA FROM THE 1991/93 NATIONAL TRAVEL SURVEY

A5.4.1 Dependent Variable = Distance per person / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.39	0.39	15488	0.00
2.	PSEG1	entered	0.42	0.42	8800	0.00
3.	WDENS00	entered	0.45	0.45	6631	0.00
4.	PWORKERS	entered	0.47	0.47	5424	0.00
5.	SETT_LON	entered	0.48	0.48	4531	0.00
6.	PSEG2	entered	0.49	0.49	3909	0.00
7.	PBSFREQ1	entered	0.50	0.50	3480	0.00
8.	PSEG4	entered	0.51	0.51	3099	0.00
9.	PHHLICS2	entered	0.51	0.51	2797	0.00
10.	PAGE0510	entered	0.52	0.52	2563	0.00
11.	PHHSTR1	entered	0.52	0.52	2359	0.00
12.	PAGE1115	entered	0.52	0.52	2192	0.00
13.	PHHSTR11	entered	0.53	0.52	2046	0.00
14.	PHHSTR4	entered	0.53	0.53	1918	0.00
15.	PRLY06	entered	0.53	0.53	1806	0.00
16.	PRETIRED	entered	0.53	0.53	1706	0.00
17.	PBSTOP13	entered	0.53	0.53	1618	0.00
18.	PPTWRKRS	entered	0.54	0.54	1540	0.00
19.	PWORKERS	removed	0.54	0.54	1630	0.00
20.	PBSTOP43	entered	0.54	0.54	1550	0.00
21.	LDENS10	entered	0.54	0.54	1479	0.00
22.	PLOCACHI	entered	0.54	0.54	1412	0.00
23.	PCITY26	entered	0.54	0.54	1357	0.00
24.	PAGE0004	entered	0.54	0.54	1301	0.00
25.	PAGE5059	entered	0.55	0.54	1253	0.00
26.	PAGE1619	entered	0.55	0.55	1210	0.00
27.	PSTUDENT	entered	0.55	0.55	1167	0.00
28.	PAGE2029	entered	0.55	0.55	1130	0.00
29.	PCITY43	entered	0.55	0.55	1093	0.00
30.	PCITY43	entered	0.55	0.55	1058	0.00
31.	SETT_250	entered	0.55	0.55	1025	0.00
32.	PAGE6069	entered	0.55	0.55	995	0.00
33.	PAGE1115	removed	0.55	0.55	1029	0.00
34.	PSEG5	entered	0.55	0.55	998	0.00
35.	PHHSTR12	entered	0.56	0.55	969	0.00
36.	PBSTOP26	entered	0.56	0.56	941	0.00
37.	PHHLICS1	entered	0.56	0.56	914	0.00
38.	PHHSTR10	entered	0.56	0.56	889	0.00
39.	PHHSTR2	entered	0.56	0.56	865	0.00
40.	PRLY13	entered	0.56	0.56	842	0.00
41.	PCITY06	entered	0.56	0.56	820	0.00
42.	LDENS05	entered	0.56	0.56	799	0.00
43.	PAGE3039	entered	0.56	0.56	779	0.00
44.	WDENS10	entered	0.56	0.56	760	0.00
45.	LDENS00	entered	0.56	0.56	742	0.00
46.	PHHSTR3	entered	0.56	0.56	725	0.00
47.	SETT_025	entered	0.56	0.56	709	0.00
48.	SETT_100	entered	0.56	0.56	693	0.00
49.	PHHSTR5	entered	0.56	0.56	678	0.00
50.	PAGE1115	entered	0.56	0.56	664	0.00
51.	PHHSTR8	entered	0.56	0.56	650	0.00

Multiple R	0.748
R Square	0.560
Adjusted R Square	0.559
Standard Error	52.665
Mean Absolute Deviation	41.3

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE0004	-0.730	0.128	-0.046	3.560	-5.687	0.000
PAGE0510	-1.227	0.133	-0.083	4.461	-9.226	0.000
PAGE1115	0.561	0.127	0.033	2.958	4.420	0.000
PAGE1619	-2.092	0.126	-0.104	2.136	-16.636	0.000
PAGE2029	-0.881	0.085	-0.067	2.285	-10.381	0.000
PAGE3039	-0.202	0.065	-0.017	1.714	-3.116	0.002
PAGE5059	-0.777	0.068	-0.069	1.969	-11.461	0.000
PAGE6069	-0.414	0.067	-0.037	1.914	-6.179	0.000
PFTWRKRS	0.749	0.058	0.096	3.026	12.827	0.000
PRETIRED	-0.945	0.069	-0.109	3.477	-13.697	0.000
PSTUDENT	1.291	0.109	0.071	1.989	11.826	0.000
PSEG1	0.758	0.027	0.173	2.128	27.633	0.000
PSEG2	0.309	0.032	0.049	1.410	9.544	0.000
PSEG4	-0.548	0.040	-0.073	1.554	-13.746	0.000
PSEG5	-0.505	0.069	-0.036	1.344	-7.355	0.000
PHHLICS1	-0.166	0.034	-0.032	2.242	-4.924	0.000
PHHLICS2	0.251	0.031	0.063	3.327	8.051	0.000
PHHSTR1	1.007	0.078	0.070	1.606	12.996	0.000
PHHSTR2	0.522	0.096	0.031	1.764	5.448	0.000
PHHSTR3	0.281	0.077	0.019	1.515	3.670	0.000
PHHSTR4	0.580	0.050	0.072	2.107	11.585	0.000
PHHSTR5	0.257	0.068	0.025	2.505	3.751	0.000
PHHSTR8	-0.155	0.045	-0.025	2.791	-3.436	0.001
PHHSTR10	0.353	0.058	0.032	1.550	6.062	0.000
PHHSTR11	-0.322	0.052	-0.046	3.046	-6.149	0.000
PHHSTR12	0.312	0.052	0.030	1.350	5.963	0.000
CARSPP	63.691	1.594	0.313	3.341	39.945	0.000
PLOCACHI	-0.455	0.031	-0.105	2.860	-14.574	0.000
PCITY06	0.184	0.047	0.025	2.128	3.943	0.000
PCITY26	0.235	0.024	0.056	1.828	9.608	0.000
PCITY43	0.290	0.035	0.045	1.633	8.278	0.000
PBSTOP13	0.419	0.040	0.049	1.170	10.494	0.000
PBSTOP26	-0.565	0.087	-0.033	1.437	-6.488	0.000
PBSTOP43	1.750	0.159	0.054	1.315	11.036	0.000
PBSFREQ1	0.353	0.027	0.087	2.350	13.232	0.000
PRLY06	0.212	0.029	0.040	1.614	7.263	0.000
PRLY13	-0.113	0.026	-0.024	1.703	-4.369	0.000
PRLY43	-0.191	0.021	-0.047	1.482	-8.949	0.000
SETT_LON	-38.452	1.401	-0.158	1.804	-27.451	0.000
SETT_250	-10.992	1.220	-0.044	1.316	-9.006	0.000
SETT_100	-3.553	1.236	-0.014	1.254	-2.876	0.004
SETT_025	-4.501	1.354	-0.017	1.377	-3.324	0.001
WDENS00	10.903	1.140	0.063	2.377	9.562	0.000
WDENS10	-3.814	1.132	-0.016	1.231	-3.370	0.000
LDENS00	3.529	1.120	0.022	2.602	3.152	0.000
LDENS05	6.697	1.224	0.028	1.437	5.471	0.000
LDENS10	-11.800	1.406	-0.041	1.297	-8.391	0.000
(Constant)	117.344	6.567			17.869	0.000


Actual Value
Predicted Value
0
100
200
300
400

A5.4.2 Dependent Variable = Distance per person / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	*R^2*	*Adjusted R^2*	*F*	*Significance*
1.	CARSPP	Entered	0.39	0.39	15448	0.00
2.	PSEG1	entered	0.42	0.42	8800	0.00
3.	PWORKERS	entered	0.44	0.44	6356	0.00
4.	PSEG4	entered	0.45	0.45	4937	0.00
5.	PSEG3	entered	0.45	0.45	3968	0.00
6.	PSEG5	entered	0.45	0.45	3326	0.00

Multiple R	0.673
R Square	0.453
Adjusted R Square	0.453
Standard Error	58.645
Mean Absolute Deviation	45.9

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	82.841	1.316	0.407	1.835	62.958	0.000
PSEG1	0.663	0.031	0.151	2.121	21.744	0.000
PSEG3	-0.249	0.030	-0.049	1.495	-8.420	0.000
PSEG4	-0.883	0.041	-0.118	1.310	-21.648	0.000
PSEG5	-0.575	0.073	-0.042	1.213	-7.917	0.000
PWORKERS	1.061	0.038	0.148	1.239	27.867	0.000
(Constant)	63.146	2.488			25.381	0.000

A5.4.3 Dependent Variable = Cars per person / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	PHHLICS0	entered	0.56	0.56	32538	0.00
2.	PHHLICS1	entered	0.69	0.69	28241	0.00
3.	PHHLICS2	entered	0.73	0.73	22238	0.00
4.	PBSFREQ1	entered	0.74	0.74	17705	0.00
5.	PSEG1	entered	0.75	0.75	14861	0.00
6.	PCITY13	entered	0.75	0.75	12771	0.00
7.	PBSTOP13	entered	0.76	0.76	11170	0.00
8.	PSTUDENT	entered	0.76	0.76	9923	0.00
9.	PHHSTR10	entered	0.76	0.76	9024	0.00
10.	PAGE4049	entered	0.77	0.77	8226	0.00
11.	PSEG3	entered	0.77	0.77	7576	0.00
12.	PRLY13	entered	0.77	0.77	7028	0.00
13.	PCITY43	entered	0.77	0.77	6572	0.00
14.	PCITY06	entered	0.78	0.78	6207	0.00
15.	PAGE5059	entered	0.78	0.78	5849	0.00
16.	PAGE3039	entered	0.78	0.78	5546	0.00
17.	PHHSTR1	entered	0.78	0.78	5281	0.00
18.	SETT_MET	entered	0.78	0.78	5039	0.00
19.	PSEG2	entered	0.79	0.79	4809	0.00
20.	PSEG5	entered	0.79	0.79	4612	0.00
21.	PSEG4	entered	0.79	0.79	4431	0.00
22.	PLOCACLO	entered	0.79	0.79	4273	0.00
23.	PUNEMPLO	entered	0.79	0.79	4114	0.00
24.	PHHSTR4	entered	0.79	0.79	3970	0.00
25.	PAGE0510	entered	0.79	0.79	3834	0.00
26.	SETT_250	entered	0.79	0.79	3703	0.00
27.	PLOCACHI	entered	0.79	0.79	3579	0.00
28.	PHHSTR6	entered	0.79	0.79	3461	0.00
29.	PHHSTR12	entered	0.79	0.79	3351	0.00
30.	LDENS15	entered	0.80	0.80	3249	0.00
31.	LDENS20	entered	0.80	0.80	3150	0.00
32.	PRLY06	entered	0.80	0.80	3058	0.00
33.	SETT_025	entered	0.80	0.80	2971	0.00
34.	PBSTOP43	entered	0.80	0.80	2889	0.00
35.	PRETIRED	entered	0.80	0.80	2812	0.00
36.	PCITY26	entered	0.80	0.80	2739	0.00
37.	SETT_050	entered	0.80	0.80	2667	0.00
38.	PAGE6069	entered	0.80	0.80	2599	0.00
39.	WDENS40	entered	0.80	0.80	2534	0.00
40.	PBSFREQ2	entered	0.80	0.80	2472	0.00
41.	WDENS30	entered	0.80	0.80	2414	0.00
42.	WDENS10	entered	0.80	0.80	2359	0.00
43.	LDENS10	entered	0.80	0.80	2305	0.00
44.	PHHSTR5	entered	0.80	0.80	2254	0.00
45.	PHHSTR2	entered	0.80	0.80	2205	0.00
46.	SETT_LON	entered	0.80	0.80	2158	0.00
47.	PRLY43	entered	0.80	0.80	2113	0.00
48.	PHHSTR7	entered	0.80	0.80	2069	0.00
49.	PAGE1115	entered	0.80	0.80	2027	0.00
50.	PAGE0004	entered	0.80	0.80	1987	0.00
51.	PWORKERS	entered	0.80	0.80	1949	0.00
52.	PHHSTR11	entered	0.80	0.80	1912	0.00
53.	PHHSTR8	entered	0.80	0.80	1876	0.00
54.	PAGE2029	entered	0.80	0.80	1842	0.00

Multiple R	0.894
R Square	0.799
Adjusted R Square	0.798
Standard Error	0.175
Mean Absolute Deviation	0.14

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
PAGE1115	-0.002	0.000	-0.019	1.448	-5.347	0.000
PAGE1619	0.003	0.000	0.028	2.033	6.761	0.000
PAGE2029	-0.002	0.000	-0.032	2.572	-6.839	0.000
PAGE3039	0.001	0.000	0.023	2.782	4.861	0.000
PAGE4049	0.002	0.000	0.033	2.719	7.006	0.000
PAGE5059	0.003	0.000	0.047	2.770	9.857	0.000
PAGE6069	0.002	0.000	0.033	2.158	7.854	0.000
PFTWRKRS	0.002	0.000	0.056	4.661	8.964	0.000
PPTWRKRS	-0.002	0.000	-0.026	1.649	-7.001	0.000
PUNEMPLO	-0.004	0.000	-0.041	1.948	-10.046	0.000
PRETIRED	-0.003	0.000	-0.062	3.776	-11.012	0.000
PSTUDENT	-0.007	0.000	-0.076	2.460	-16.639	0.000
PSEG1	0.002	0.000	0.105	3.749	18.661	0.000
PSEG2	-0.002	0.000	-0.049	2.336	-11.017	0.000
PSEG3	-0.002	0.000	-0.080	3.084	-15.648	0.000
PSEG4	-0.003	0.000	-0.075	2.156	-17.685	0.000
PSEG5	-0.006	0.000	-0.086	1.551	-23.799	0.000
PHHLICS0	-0.018	0.000	-0.617	4.413	-101.499	0.000
PHHLICS1	-0.011	0.000	-0.418	4.321	-69.465	0.000
PHHLICS2	-0.006	0.000	-0.292	6.239	-40.369	0.000
PHHSTR1	-0.006	0.000	-0.083	1.772	-21.420	0.000
PHHSTR3	-0.003	0.000	-0.035	1.661	-9.397	0.000
PHHSTR4	-0.002	0.000	-0.041	2.698	-8.602	0.000
PHHSTR5	-0.001	0.000	-0.022	2.126	-5.129	0.000
PHHSTR7	0.001	0.000	0.012	1.865	3.113	0.002
PHHSTR8	-0.001	0.000	-0.030	2.238	-6.831	0.000
PHHSTR10	0.002	0.000	0.044	1.797	11.372	0.000
PHHSTR11	-0.001	0.000	-0.016	2.043	-3.890	0.000
PLOCACHI	0.000	0.000	-0.010	1.910	-2.397	0.017
PLOCACLO	-0.005	0.001	-0.031	1.264	-9.374	0.000
PCITY13	-0.002	0.000	-0.049	1.820	-12.644	0.000
PCITY26	0.001	0.000	0.037	1.981	9.112	0.000
PBSTOP06	0.000	0.000	-0.010	1.090	-3.184	0.002
PBSTOP13	0.002	0.000	0.037	1.203	11.778	0.000
PBSTOP26	0.002	0.000	0.027	1.496	7.614	0.000
PBSTOP43	0.005	0.001	0.033	1.341	9.994	0.000
PBSFREQ1	0.001	0.000	0.074	2.858	15.144	0.000
PBSFREQ2	0.000	0.000	-0.009	1.397	-2.706	0.007
PRLY06	-0.002	0.000	-0.057	1.639	-15.407	0.000
PRLY13	-0.001	0.000	-0.024	1.820	-6.068	0.000
PRLY26	0.000	0.000	-0.021	1.261	-6.382	0.000
PRLY43	-0.001	0.000	-0.029	1.450	-8.230	0.000
SETT_LON	-0.030	0.005	-0.025	2.087	-6.046	0.000
SETT_MET	-0.028	0.004	-0.026	1.753	-6.670	0.000
SETT_100	0.016	0.004	0.013	1.363	3.755	0.000
SETT_025	0.048	0.005	0.036	1.539	10.024	0.000
SETT_003	0.028	0.004	0.028	1.573	7.723	0.000
WDENS00	0.037	0.005	0.043	4.238	7.273	0.000
WDENS10	0.027	0.005	0.023	2.017	5.700	0.000
WDENS20	0.017	0.005	0.015	2.000	3.745	0.000
WDENS30	0.052	0.004	0.046	1.848	11.672	0.000
WDENS40	0.013	0.005	0.010	1.658	2.662	0.008
LDENS00	-0.051	0.004	-0.064	2.950	-12.896	0.000
LDENS05	0.010	0.004	0.009	1.544	2.412	0.016
(Constant)	2.118	0.023			90.619	0.000

A5.5 Summary of Results For Regression Analyses where the Dependent Variable is Distance per Person and the Independent Variables are Socio-Economic and Land Use Characteristics

Data source → *Independent variable[1]* ↓	*NTS 1978/79[2]*	*NTS 1985/86[2]*	*NTS 1989/91[2]*	*NTS 1991/93[2]*	*Comments*
PAGE0004			–	–	No conclusions about the effect of the proportion of different age groups on travel distance.
PAGE0510	+ +	–	–	– –	
PAGE1115	+			+	
PAGE1619	+		– –	– – –	
PAGE2029	+ +	+	+	– –	
PAGE3039	+	+		–	
PAGE4049	+	+	+ +		
PAGE5059	– –	+ +	–	– –	
PAGE6069	– –	+	–	–	
PUNEMPLO	+		+		No conclusions about the effect of the proportion of students, employed, unemployed or retired people on average travel distance.
PRETIRED	+		–	– – –	
PSTUDENT	+		+ +	+ +	
PWORKERS		+ + +			
PFTWRKRS	+	–	+ + +	+ +	No conclusions about the effect of the proportion of part-time and full-time workers on average travel distance.
PPTWRKRS					
PHHLICS0					Average travel distance is lowest in areas where a high proportion of households have no driving licence.
PHHLICS1	+ +	–	+	–	
PHHLICS2	+ + +	+ +	+ + +	+ +	
PWORKRS0					
PWORKRS1					
PWORKRS2					
PADULTS1					
PADULTS2					
PADULTS3					
PADULTS4	*Variables excluded from regression analysis due to high multicollinearity.*				
PADULTS5					
PCHILD0					
PCHILD1					
PCHILD2					
PCHILD3					
PCHILD4					
PSEG1	+ + +	+ + +	+ + +	+ + +	Average travel distances are highest in areas where the proportions of households in socio-economic group 1 is high and lowest in areas where the proportion of households in socio-economic groups 3, 4 and 5 is high.
PSEG2	+ +	+ + +		+	
PSEG3	– –		–		
PSEG4	–	+	– –	– –	
PSEG5	–		–	–	

1. Refer to Appendix 4 for an explanation of the independent variables included in the regression analysis.
2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

Data source → *Independent variable*[1] ↓	*NTS 1978/79*[2]	*NTS 1985/86*[2]	*NTS 1989/91*[2]	*NTS 1991/93*[2]	*Comments*
PHHSTR1	+	+		+ +	No conclusions about the effect of the proportion of different household structures on average travel distance.
PHHSTR2	–		–	+	
PHHSTR3	+	+	+	+	
PHHSTR4	+ +	+		+ +	
PHHSTR5			–	+	
PHHSTR6			+		
PHHSTR7	+		–		
PHHSTR8				–	
PHHSTR9	+	–			
PHHSTR10	+	– –	– –	+	
PHHSTR11	–		–	–	
PHHSTR12	– –		–	+	
CARSPP	+ + +	+ + +	+ + +	+ + +	Average travel distance increases as the average number of cars per person increases.
PLOCACHI		–	– –	– – –	Average travel distance is often shorter where the proximity to local facilities (post office, chemist, grocers) is high.
PLOCACLO	+		+		
PCITY06		+		+	No conclusions about the effect of the proximity to high street shops on average travel distance.
PCITY13	– –	– –	–		
PCITY26	–	–	– –	+ +	
PCITY43	–	–	– –	+	
PBSTOP03	*Variable excluded due to high multicollinearity*				
PBSTOP06	+	–			No conclusions about the effect of the proximity to a bus stop on travel distance.
PBSTOP13	–	–	–	+	
PBSTOP26	+	+	–	–	
PBSTOP43	–	+		+ +	
PBSFREQ1	+	+ +	–	+ +	Average travel distance is often higher in areas where the local bus frequency is less than 2 buses per hour.
PBSFREQ2	–				
PRLY06	–			+	No conclusions about the effect of the proximity to a railway station on average travel distance.
PRLY13	–	+ +	+ +	–	
PRLY26	–	–			
PRLY43	–	+	+	–	
SETT_LON	–	–	– – –	– – –	Average travel distance is consistently lower in London and other large urban areas containing more than 250,000 residents (including the metropolitan areas). No conclusions about the effect of other settlement size on average travel distance.
SETT_MET	–		– – –		
SETT_250	–		– –	–	
SETT_100	+	+	–	–	
SETT_050		+	– –		
SETT_025	–	–	– – –	–	
SETT_003		+	– –		
WDENS00	–	+ +	+ +	+ +	Average travel distance is often higher in areas with low ward-level population density (less than 10 persons per hectare) since 1985/86.
WDENS10				–	
WDENS20	+				
WDENS30	+ +		–		
WDENS40	–	–	+		

1. Refer to Appendix 4 for an explanation of the independent variables included in the regression analysis.

2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

Data source → *Independent variable*[1] ↓	*NTS 1978/79*[2]	*NTS 1985/86*[2]	*NTS 1989/91*[2]	*NTS 1991/93*[2]	*Comments*
LDENS00	+ +		+	+	No conclusions about the effect of local authority population density on average travel distance.
LDENS05	n.a.	+	–	+	
LDENS10	n.a.	+		–	
LDENS15	n.a.				
LDENS20	–				
Sample size (number of survey areas)	712	720	719	738	

1. Refer to Appendix 4 for an explanation of the independent variables included in the regression analysis.
2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

A5.6 Summary of Results For Regression Analyses where the Dependent Variable is the Ratio of Cars per Person and the Independent Variables are Socio-Economic and Land Use Characteristics

Data source → *Independent variable*[1] ↓	*NTS 1978/79*[2]	*NTS 1985/86*[2]	*NTS 1989/91*[2]	*NTS 1991/93*[2]	*Comments*
PAGE0004			–		The number of cars per person is often highest in areas with a large proportion of persons aged between 40 and 59.
PAGE0510	–		– –		
PAGE1115		+ +	–	–	
PAGE1619	– –	–		+	
PAGE2029	–	+	–	–	
PAGE3039	–	+	+ +	+	
PAGE4049	+	+	+ +	+	
PAGE5059	+	+ +	+ +	+	
PAGE6069		+ +	+	+	
PUNEMPLO	–	– –	– –	–	No conclusions about the effect of the proportion of students, employed, unemployed or retired people on car ownership.
PRETIRED		–	–	– –	
PSTUDENT		– –	– –	– –	
PWORKERS	+ +		–		
PFTWRKRS				+ +	No conclusions about the effect of the proportion of part-time and full-time workers on car ownership.
PPTWRKRS				–	
PHHLICS0	– – –	– – –	– – –	– – –	Car ownership is highest in areas where there is a high proportion of driving licences.
PHHLICS1	– – –	– – –	– – –	– – –	
PHHLICS2	– – –	– – –	– – –	– – –	
PWORKRS0					*Variables excluded from regression analysis due to high multicollinearity.*
PWORKRS1					
PWORKRS2					
PADULTS1					
PADULTS2					
PADULTS3					
PADULTS4					
PADULTS5					
PCHILD0					
PCHILD1					
PCHILD2					
PCHILD3					
PCHILD4					
PSEG1	+ + +	+ + +	–	+ + +	Car ownership is highest in areas where the proportions of households in socio-economic group 1 is high and lowest in areas where the proportion of households in socio-economic groups 4 and 5 is high.
PSEG2	+		– – –	–	
PSEG3	+	– –	– – –	– –	
PSEG4	–	–	– –	– –	
PSEG5	–	–	– –	– –	

1. Refer to Appendix 4 for an explanation of the independent variables included in the regression analysis.
2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

Data source → *Independent variable*[1] ↓	*NTS 1978/79*[2]	*NTS 1985/86*[2]	*NTS 1989/91*[2]	*NTS 1991/93*[2]	*Comments*
PHHSTR1	–	– –	– –	– –	No conclusions about the effect of household structure on car ownership.
PHHSTR2		– –	–		
PHHSTR3	– –	–		–	
PHHSTR4	– –	– –	– –	–	
PHHSTR5	+	– –	–	–	
PHHSTR6		– – –	+		
PHHSTR7		– –	–	+	
PHHSTR8	+	– – –	+	–	
PHHSTR9		– –			
PHHSTR10	+	– –	+ +	+	
PHHSTR11		– – –	+	–	
PHHSTR12		– –	+		
PLOCACHI	– –	– –	–	–	No conclusions about the effect of the proximity to local facilities (post office, chemist, grocers) on car ownership.
PLOCACLO			– –	–	
PCITY06	–		–		No conclusions about the effect of the proximity to high street shops on car ownership.
PCITY13	+	–	– –	–	
PCITY26		–	–	+	
PCITY43	–	–	– –		
PBSTOP03	*Variable excluded due to high multicollinearity*				
PBSTOP06	+	+ +		–	No conclusions about the effect of the proximity to a bus stop on car ownership.
PBSTOP13	+	–	+ +	+	
PBSTOP26	–	+		+	
PBSTOP43			+	+	
PBSFREQ1	+	+	+	+ +	Car ownership is consistently higher in areas where the local bus frequency is less than 2 buses per hour.
PBSFREQ2	+		–	–	
PRLY06	–	– –	–	– –	Car ownership is consistently lower in areas where the nearest railway station is within than a 6-minute walk.
PRLY13	–	–	–	–	
PRLY26	+	+		–	
PRLY43	+	–	+	–	
SETT_LON	+ +		+	–	No conclusions about the effect of settlement size on car ownership.
SETT_MET	+	– –	– –	–	
SETT_250	+	– –	–		
SETT_100	–	–		+	
SETT_050	–	–	–		
SETT_025	–	–	+	+	
SETT_003		–		+	
WDENS00	+ +	–		+	No conclusions about the effect of ward population density on car ownership.
WDENS10	+	–	+	+	
WDENS20	+		–	+	
WDENS30			+	+	
WDENS40	–	–	+	+	

1. Refer to Appendix 4 for an explanation of the independent variables included in the regression analysis.
2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

Data source → *Independent variable*[1] ↓	*NTS 1978/79*[2]	*NTS 1985/86*[2]	*NTS 1989/91*[2]	*NTS 1991/93*[2]	*Comments*
LDENS00	–			– –	No conclusions about the effect of local authority population density on average travel distance.
LDENS05	n.a.	+		+	
LDENS10	n.a.	+	+		
LDENS15	n.a.		+		
LDENS20	–	+			
Sample size (number of survey areas)	712	720	719	738	

1. Refer to Appendix 4 for an explanation of the independent variables included in the regression analysis.

2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

APPENDIX 6: THE ACCURACY AND COMPARABILITY OF JOURNEY DISTANCE CALCULATIONS

This Appendix examines the accuracy of the estimates of journey distance calculated from postcode data in this study. The results of the two methods for calculating journey distance employed in this study are then compared and the extent to which the estimates of journey distance are comparable is examined.

Each of the travel survey data sets included in this study are based on household travel diary surveys in which all journeys are recorded for each member of the household. From this information it is possible to calculate the travel distance of each journey.

Travel distance was not recorded in the two county travel surveys however. Thus, travel distance was estimated using two methods. The first method (the 'straight-line' method) is based on postcode data for the origin and destination of each journey. The origin and destination postcodes were converted into Ordnance Survey grid references using the Central Postcode Directory (available through Manchester Information Data Services – MIDAS). The straight-line distance between the origin and destination for each journey was calculated from the Ordnance Survey grid references. The second method of estimating journey distance (the 'journey-speed' method) is based on information about the journey duration, time of day and mode. Travel distance for each journey was estimated using this information and making assumptions about the average speed for each mode at different times of the day.

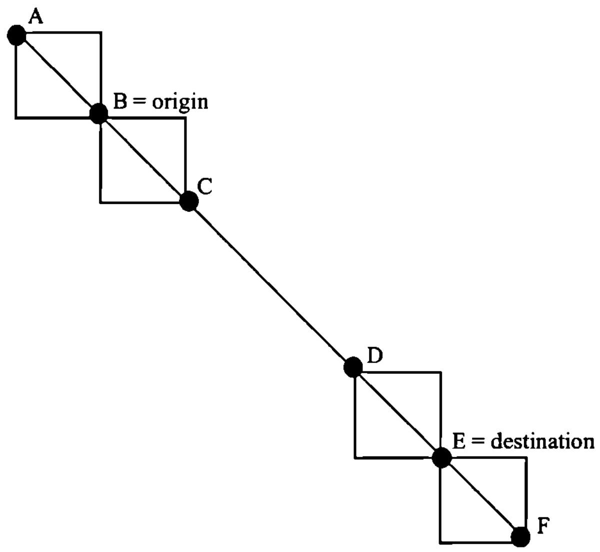
A6.1 ACCURACY OF JOURNEY DISTANCE ESTIMATES

According to the documentation for the Central Postcode Directory (Post Office, 1995), the grid reference of each postcode relates to the "first address of each postcode" – the first address when ordered alphabetically[1].

1. When the postcode includes addresses with different road names, the first address is on theroad which is first when ordered alphabetically. The first address from a list of addresses on the same road is the one with the lowest number.

Two extreme cases are identified in order to examine the accuracy of this method for estimating journey distance. In the first case, the journey origin and destination are closer together than the postcode coordinates. This is illustrated in Figure A6.1 where the origin and destination is at point B and E respectively and the journey origin and destination postcode grid reference is at point A and F respectively. Thus, the distance between the two postcode grid references is AF but the distance between the journey origin and destination is distance BE.

FIGURE A6.1 THE CALCULATION OF JOURNEY DISTANCE USING THE 'STRAIGHT-LINE' METHOD



In the second extreme case, the postcode coordinates are closer together than the origin and destination grid references. This is illustrated in Figure A6.1 where the origin and destination is at point B and E respectively and the postcode grid references of the origin and destination is at point C and D respectively. Thus, the distance between the two postcode grid references is CD but the distance between the journey origin and destination is distance BE.

The estimate of journey distance using the 'straight-line' method is therefore within the range between CD and BE (minimum and maximum respectively). Thus, the margin of error in estimating the journey distance is ±2AB assuming that the origin and destination postcodes have the same area (and therefore AB=BC=DE=EF).

Data from the city of Leicester are used to quantify this margin of error. Within the city of Leicester, which has an area of approximately 7,330 hectares, there are 6,676 separate postcodes. Hence, the typical postcode covers an area of approximately 1.1 hectares. If the typical postcode area were square, it would therefore measure approximately 105 x 105 metres (one hectare is equal to 10,000 square metres). The distance AB (from Figure A3.1) can be calculated using Pythagoras' Theorem with these dimensions:

$$AB^2 = 105^2 + 105^2$$

So, $$AB = 148$$

The maximum margin of error in estimating journey distance from postcode data is therefore just under ± 300 metres (± 2AB). In addition, a further inaccuracy of up to ± 50 metres must be introduced into the estimates of journey distance since each of the Ordnance Survey grid references for the postcodes recorded in the Central Postcode Directory have a resolution of 100 metres (Post Office, 1995). In total this amounts to a maximum margin of error of ± 400 metres (since both origin and destination postcode grid references are accurate to within ± 50 metres).

A6.2 Comparability of Journey Distance Estimates

This section compares the results of both methods for calculating journey distance ('straight-line' and 'journey-speed' method) and examines the extent to which the estimates are comparable. Travel distances were estimated for each journey by the 'straight-line' and 'journey-speed' method (described in chapter 8) using travel data from Leicestershire and Kent. Two values of travel distances were then calculated for each person included in the survey.

Correlation analysis of the two values shows close correspondence between the two methods for estimating travel distance (Table A6.1). The correlation coefficient between the between 'straight-line' distance and 'journey-speed' distance is 0.91 for the Kent data and 0.89 for the Leicestershire data. Both sets of data show similar levels of correlation. The 'straight-line' distance is lower than the 'journey-speed' distance as would be expected since the actual journey distance will always be longer than the straight-line distance. Evidence from the Kent data suggests that the 'straight-line' distance is on average 9 per cent below the 'journey-speed' distance. Evidence from the Leicestershire data suggests that the 'straight-line' distance is 14 per cent below the 'journey-speed' distance. Thus, both sets of data show similar levels of correspondence between the results of the two methods for calculating journey distance and indicate that 'straight-line' distance is around 10 per cent lower than the 'journey time' distance.

TABLE A6.1 COMPARISON OF RESULTS FROM THE TWO METHODS OF ESTIMATING JOURNEY DISTANCE

Data source	*Correlation coefficient*[1]	*Ratio of 'straight-line' distance and 'journey-speed' distance*
Kent	0.91	0.91
Leicestershire	0.89	0.86

1. Coefficient for the correlation between 'straight-line' distance and 'journey-speed' distance.

APPENDIX 7: THE KENT WARDS EXAMINED IN THE STUDY

Gillingham wards:
- Beeching
- Brompton
- Hempstead and Wigmore
- Medway
- North
- Priestfield
- South
- Twydall
- Watling Street

Maidstone wards:
- Barming
- Bearsted
- Boughton and Monchelsea
- Boxley
- Bridge
- East
- Farleigh
- Heath
- High Street
- Langley
- Loose
- North
- Park Wood
- Shepway East
- Shepway West
- South
- Thurnham

Rochester upon Medway wards:
- Cuxton and Halling
- Earl
- Frindsbury
- Frindsbury Extra
- Holcombe
- Horsted
- Lordswood
- Luton
- Rede Court
- St. Margarets
- Temple Farm
- Town
- Troy Town
- Walderslade
- Warren Wood
- Wayfield
- Weedswood

Tonbridge and Malling wards:
- Aylesford and Eccles
- Blue Bell Hill
- Burham and Wouldham
- Larkfield
- Snodland

APPENDIX 8: THE LEICESTERSHIRE WARDS EXAMINED IN THE STUDY

Blaby wards:
- Cosby
- Countesthorpe
- Croft Hill
- Enderby
- Fosse
- Glen Parva
- Kirby
- Leicester Forest East
- Millfield
- Narborough
- Normanton
- St. Johns
- Winchester

Charnwood wards:
- Barrow Upon Soar and Quorndon
- Birstall Goscote
- Birstall Greengate
- Birstall Riverside
- Birstall Stonehill
- Bradgate
- East Goscote
- Mountsorrel and Rothley
- Queniborough
- Syston
- Thurmaston

Harborough wards:
- Glen
- Houghton
- Kibworth
- Scraptoft
- Thurnby

Hinckley and Bosworth ward:
- Groby

Leicester wards:
- Abbey
- Belgrave
- Coleman
- Evington
- Eyres Monsell
- Humberstone
- Latimer
- New Parks
- North Bridge
- Rowley Fields
- Rushey Mead
- Saffron
- St. Augustine's
- Stoneygate
- Thurncourt
- Western Park
- West Humberstone

Oadby and Wigston wards:
- Bassett
- Brocks Hill
- Brookside
- Central
- Fairfield
- Grange
- St. Peter's
- St. Wolstan's
- Westfield

APPENDIX 9: SOCIO-ECONOMIC AND LAND USE VARIABLES ANALYSED AT THE SURVEY AREA LEVEL USING THE KENT TRAVEL SURVEY DATA

Variable type	Variable name		Description
1. Socio-economic status	PSEG1		percentage of households whose head is in managerial employment
	PSEG2		percentage of households whose head is in skilled non-manual employment
	PSEG3		percentage of households whose head is in skilled manual employment
	PSEG4		percentage of households whose head is in semi-skilled employment
	PSEG5		percentage of households whose head is in unskilled employment
2. Household car ownership	CARSPP		number of cars per person
3. Persons in employment	PWORKERS		percentage of residents in paid employment (as a proportion of the total population)
4. Ward-level population density	WDENS00	=1	if the household is in a ward where the population density is less than 10 persons per hectare
	WDENS10	=1	if the household is in a ward where the population density is between 10 and 20 persons per hectare
	WDENS20	=1	if the household is in a ward where the population density is between 20 and 30 persons per hectare
	WDENS30	=1	if the household is in a ward where the population density is between 30 and 40 persons per hectare
	WDENS40	=1	if the household is in a ward where the population density is between 40 and 50 persons per hectare
5. Job ratio	JRBAL	=1	if the ratio between jobs and workers in the ward is between 0.5 and 1.5
	JRHIGH	=1	if the ratio between jobs and workers is more than 1.5
6. Proximity to a motorway junction	MOTORWAY	=1	if there is a motorway junction in the ward
7. Proximity to a railway station	RAILWAY	=1	if there is a railway station in the ward
8. Parking restraint	RES_PARK	=1	if there is parking restraint in the ward

APPENDIX 10: RESULTS OF THE REGRESSION OF AVERAGE DISTANCE PER PERSON PER WEEK AT THE SURVEY AREA LEVEL OF ANALYSIS: KENT TRAVEL SURVEY DATA

A10.1.1 Dependent Variable = Distance per person ('straight-line' distance) / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	PSEG1	entered	0.47	0.47	11426	0.00
2.	CARSPP	entered	O.55	0.55	7749	0.00
3.	PSEG3	entered	0.62	0.62	6832	0.00
4.	PSEG5	entered	0.69	0.69	6947	0.00
5.	PSEG2	entered	0.71	0.71	6334	0.00
6.	WORKERS	entered	0.72	0.72	5479	0.00
7.	PSEG4	entered	0.72	0.72	4732	0.00

Multiple R	0.850
R Square	0.722
Adjusted R Square	0.722
Standard Error	18.725
Mean Absolute Deviation	12.7

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	239.159	3.332	0.497	2.199	71.786	0.000
PSEG1	128.103	3.520	0.381	5.023	36.390	0.000
PSEG2	103.475	4.474	0.162	2.245	23.129	0.000
PSEG3	471.105	9.579	0.297	1.675	49.183	0.000
PSEG4	-128.085	15.188	-0.051	1.678	-8.433	0.000
PSEG5	-641.696	12.774	-0.269	1.312	-50.234	0.000
PWORKERS	88.762	4.817	0.124	2.088	18.426	0.000
(Constant)	-90.561	2.309			-39.213	0.000

A10.1.2 Dependent Variable = Distance per person ('journey-time' distance) / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.35	0.35	6794	0.00
2.	PSEG3	entered	0.47	0.47	5634	0.00
3.	PSEG5	entered	0.61	0.61	6546	0.00
4.	PWORKERS	entered	0.64	0.64	5734	0.00
5.	PSEG1	entered	0.65	0.65	4767	0.00
6.	PSEG5	entered	0.69	0.69	4660	0.00
7.	PSEG2	entered	0.69	0.69	4003	0.00

Multiple R	0.829
R Square	0.687
Adjusted R Square	0.687
Standard Error	15.488
Mean Absolute Deviation	11.1

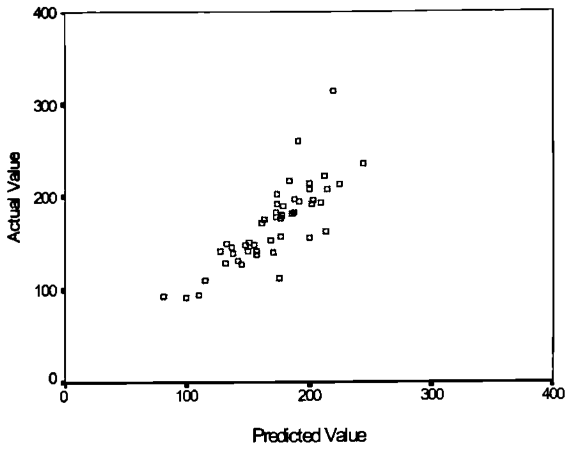
Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	216.820	2.756	0.578	2.199	78.686	0.000
PSEG1	106.564	2.912	0.406	5.023	36.600	0.000
PSEG2	146.525	3.700	0.294	2.245	39.598	0.000
PSEG3	579.546	7.922	0.469	1.675	73.153	0.000
PSEG4	-54.387	12.562	-0.028	1.678	-4.330	0.000
PSEG5	-514.785	10.565	-0.276	1.312	-48.723	0.000
PWORKERS	25.435	3.984	0.046	2.088	6.384	0.000
(Constant)	-38.346	1.910			-20.075	0.000

A10.1.3 Dependent Variable = Distance per person ('straight-line' distance) / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	PSEG1	entered	0.47	0.47	11426	0.00
2.	CARSPP	entered	0.55	0.55	7749	0.00
3.	PSEG3	entered	0.62	0.62	6832	0.00
4.	PSEG5	entered	0.69	0.69	6947	0.00
5.	PSEG2	entered	0.71	0.71	6334	0.00
6.	WDENS00	entered	0.74	0.74	5939	0.00
7.	PWORKERS	entered	0.75	0.75	5343	0.00
8.	JRHIGH	entered	0.75	0.75	4809	0.00
9.	JRBAL	entered	0.76	0.76	4564	0.00
10.	WDENS40	entered	0.77	0.77	4182	0.00
11.	MOTORWAY	entered	0.77	0.77	3843	0.00
12.	WDENS30	entered	0.77	0.77	3552	0.00
13.	WDENS20	entered	0.77	0.77	3337	0.00
14.	WDENS10	entered	0.78	0.78	3165	0.00
15.	RAILWAY	entered	0.78	0.78	2965	0.00
16.	RES_PARK	entered	0.78	0.78	2781	0.00

Multiple R	0.882
R Square	0.777
Adjusted R Square	0.777
Standard Error	16.764
Mean Absolute Deviation	11.4

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	209.705	4.068	0.436	4.090	51.547	0.000
JRBAL	-8.773	0.409	-0.123	1.884	-21.438	0.000
JRHIGH	-10.766	0.590	-0.109	2.055	-18.260	0.000
MOTORWAY	-4.286	0.628	-0.038	1.809	-6.829	0.000
RES_PARK	-1.513	0.608	-0.013	1.671	-2.488	0.013
RAILWAY	2.212	0.383	0.027	1.254	5.776	0.000
PSEG1	92.980	3.448	0.276	6.012	26.968	0.000
PSEG2	85.128	4.240	0.133	2.516	20.079	0.000
PSEG3	256.200	9.739	0.162	2.161	26.306	0.000
PSEG5	-583.305	13.291	-0.244	1.773	-43.887	0.000
PWORKERS	105.228	4.966	0.147	2.769	21.189	0.000
WDENS00	4.922	0.860	0.056	5.492	5.720	0.000
WDENS10	-11.377	0.802	-0.086	2.086	-14.188	0.000
WDENS20	-14.809	0.739	-0.184	4.820	-20.038	0.000
WDENS30	-15.950	0.763	-0.162	3.437	-20.904	0.000
WDENS40	-16.481	0.645	-0.177	2.733	-25.569	0.000
(Constant)	-41.613	2.374			-17.530	0.000



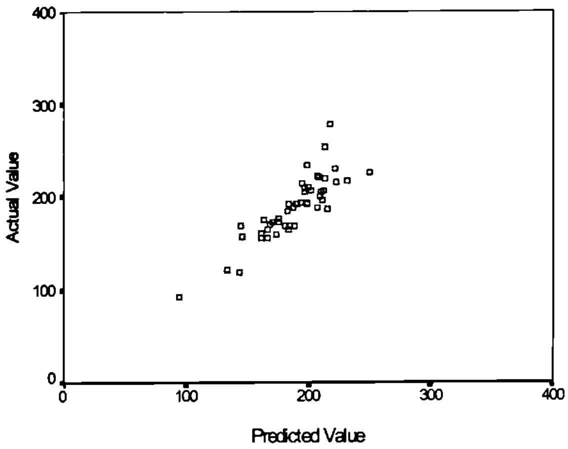
400
300
200
100
0
Actual Value
0
100
200
300
400
Predicted Value

A10.1.4 Dependent Variable = Distance per person ('journey-time' distance) / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.35	0.35	6794	0.00
2.	PSEG3	entered	0.47	0.47	5634	0.00
3.	PSEG5	entered	0.61	0.61	6546	0.00
4.	PWORKERS	entered	0.64	0.64	5734	0.00
5.	RAILWAY	entered	0.67	0.67	5173	0.00
6.	WDENS40	entered	0.69	0.69	4788	0.00
7.	JRBAL	entered	0.71	0.71	4481	0.00
8.	JRHIGH	entered	0.73	0.73	4399	0.00
9.	WDENS20	entered	0.74	0.74	4037	0.00
10.	PSEG2	entered	0.75	0.75	3766	0.00
11.	PSEG1	entered	0.76	0.76	3661	0.00
12.	RES_PARK	entered	0.77	0.77	3471	0.00
13.	MOTORWAY	entered	0.77	0.77	3324	0.00
14.	WDENS00	entered	0.78	0.78	3197	0.00
15.	PSEG4	entered	0.78	0.78	3002	0.00
16.	WDENS10	entered	0.78	0.78	2831	0.00
17.	WDENS30	entered	0.78	0.78	2702	0.00

Multiple R	0.885
R Square	0.783
Adjusted R Square	0.782
Standard Error	12.911
Mean Absolute Deviation	9.48

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	156.354	3.134	0.417	4.093	49.885	0.000
JRBAL	-11.164	0.315	-0.201	1.884	-35.416	0.000
JRHIGH	-13.252	0.455	-0.173	2.065	-29.112	0.000
MOTORWAY	-12.877	0.489	-0.148	1.855	-26.309	0.000
PSEG1	88.307	2.691	0.337	6.174	32.818	0.000
PSEG2	114.164	3.269	0.229	2.521	34.928	0.000
PSEG3	434.964	7.740	0.352	2.301	56.197	0.000
PSEG4	102.040	10.901	0.052	1.818	9.361	0.000
PSEG5	-474.983	10.265	-0.255	1.783	-46.272	0.000
PWORKERS	81.622	3.825	0.147	2.769	21.340	0.000
RAILWAY	-8.564	0.295	-0.134	1.255	-29.025	0.000
RES_PARK	-7.311	0.468	-0.083	1.672	-15.611	0.000
WDENS00	4.023	0.664	0.059	5.508	6.062	0.000
WDENS10	-7.473	0.619	-0.072	2.096	-12.070	0.000
WDENS20	-6.831	0.570	-0.109	4.829	-11.991	0.000
WDENS30	-7.014	0.591	-0.091	3.479	-11.864	0.000
WDENS40	-16.236	0.500	-0.223	2.774	-32.469	0.000
(Constant)	0.257	1.866			0.138	0.891


400
300
200
100
0
Actual Value
0
100
200
300
400
Predicted Value

Dependent variable → Independent variables[1] ↓	*'Straight-line' distance per person per week*[2]	*'Journey-speed' distance per person per week*[2]	*Comments*
CARSPP	+ + +	+ + +	Travel distance increases as the level of car ownership increases.
PSEG1	+ + +	+ + +	Travel distance is higher in areas where there is a large proportion of households in socio-economic groups 1, 2 and 3.
PSEG2	+ + +	+ + +	
PSEG3	+ + +	+ + +	
PSEG4		+ +	
PSEG5	– – –	– – –	
PWORKERS	+ + +	+ + +	Travel distance increases as the proportion of persons in paid employment increases.
JRBAL	–	– – –	Travel distance is consistently higher in areas where there is a low job ratio (less than 0.5 jobs per workers).
JRHIGH	–	– – –	
WDENS00	+ +	+ +	Travel distance is higher in areas where ward-level population density is low (less than 10 persons per hectare). Travel distance is low in wards where the density is 40-50 persons per hectare. Travel distance is higher in wards where the density is greater than 50 persons per hectare.
WDENS10	– –	– –	
WDENS20	– – –	– – –	
WDENS30	– – –	– –	
WDENS40	– – –	– – –	
MOTORWAY	–	– – –	Travel distance is lower in wards with a motorway junction.
RAILWAY	+	– – –	No consistent conclusions about the effect of the proximity to a railway station on travel distance per person.
RES_PARK	–	– –	Travel distance is consistently lower in areas where parking is limited.
Sample size (number of survey areas)	48	48	

1. Refer to Appendix 9 for an explanation of the independent variables included in the regression analysis.

2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.

APPENDIX 11: SOCIO-ECONOMIC AND LAND USE VARIABLES ANALYSED AT THE SURVEY AREA LEVEL USING THE LEICESTERSHIRE TRAVEL SURVEY DATA

Variable type	Variable name		Description
1. Socio-economic status	PSEG1		percentage of households whose head is in managerial employment
	PSEG2		percentage of households whose head is in skilled non-manual employment
	PSEG3		percentage of households whose head is in skilled manual employment
	PSEG4		percentage of households whose head is in semi-skilled employment
	PSEG5		percentage of households whose head is in unskilled employment
2. Household car ownership	CARSPP		number of cars per person
3. Persons in employment	PWORKERS		percentage of residents in paid employment (as a proportion of the total population)
4. Ward-level population density	WDENS00	=1	if the household is in a ward where the population density is less than 10 persons per hectare
	WDENS10	=1	if the household is in a ward where the population density is between 10 and 20 persons per hectare
	WDENS20	=1	if the household is in a ward where the population density is between 20 and 30 persons per hectare
	WDENS30	=1	if the household is in a ward where the population density is between 30 and 40 persons per hectare
	WDENS40	=1	if the household is in a ward where the population density is between 40 and 50 persons per hectare
5. Job ratio	JRBAL	=1	if the ratio between jobs and workers in the ward is between 0.5 and 1.5
	JRHIGH	=1	if the ratio between jobs and workers is more than 1.5
6. Proximity to a motorway junction	MOTORWAY	=1	if there is a motorway junction in the ward
7. Proximity to a railway station	RAILWAY	=1	if there is a railway station in the ward

APPENDIX 12: RESULTS OF THE REGRESSION OF DISTANCE PER PERSON PER WEEK WITH SOCIO-ECONOMIC AND LAND USE CHARACTERISTICS: LEICESTERSHIRE TRAVEL SURVEY DATA

A12.1.1 Dependent Variable = Distance per person ('straight-line' distance) / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	O.47	0.47	1658	0.00
2.	PSEG4	entered	0.52	0.52	1017	0.00
3.	PSEG5	entered	0.54	0.54	729	0.00
4.	PSEG2	entered	0.55	0.55	565	0.00
5.	PSEG1	entered	0.55	0.55	455	0.00
6.	WORKERS	entered	0.55	0.55	381	0.00

Multiple R	0.742
R Square	0.550
Adjusted R Square	0.549
Standard Error	33.433
Mean Absolute Deviation	31.1

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	148.980	10.603	0.407	3.490	14.050	0.000
PSEG1	-91.648	33.625	-0.047	1.249	-2.726	0.006
PSEG2	46.131	8.183	0.130	2.222	5.638	0.000
PSEG4	-116.497	10.104	-0.208	1.353	-11.529	0.000
PSEG5	-45.360	6.413	-0.152	1.921	-7.073	0.000
PWORKERS	23.835	11.176	0.046	1.954	2.133	0.033
(Constant)	76.415	5.706			13.392	0.000

A12.1.2 Dependent Variable = Distance per person ('journey-time' distance) / Independent Variables = Seven 'key' Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.46	0.46	1596	0.00
2.	PSEG4	entered	0.51	0.51	986	0.00
3.	PWORKERS	entered	0.54	0.54	727	0.00
4.	PSEG1	entered	0.55	0.55	574	0.00
5.	PSEG5	entered	0.56	0.56	472	0.00
6.	PSEG2	entered	0.56	0.56	395	0.00

Multiple R	0.748
R Square	0.559
Adjusted R Square	0.558
Standard Error	33.699
Mean Absolute Deviation	28.8

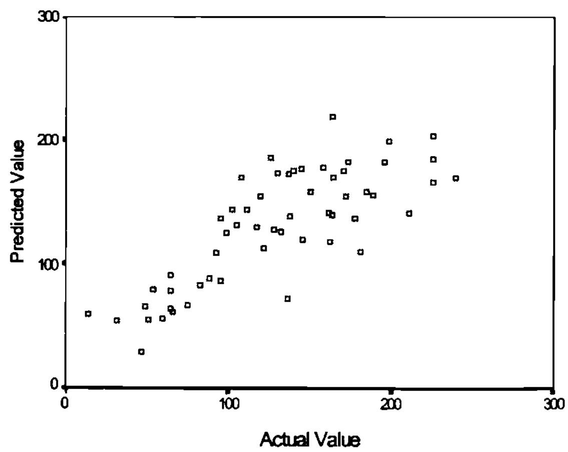
Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	133.627	9.510	0.403	3.490	14.051	0.000
PSEG1	-186.867	30.158	-0.106	1.249	-6.196	0.000
PSEG2	18.514	7.339	0.058	2.222	2.523	0.012
PSEG4	-118.837	9.063	-0.234	1.353	-13.113	0.000
PSEG5	-29.958	5.752	-0.111	1.921	-5.208	0.000
PWORKERS	84.449	10.024	0.181	1.954	8.425	0.000
(Constant)	82.015	5.118			16.026	0.000

A12.1.3 Dependent Variable = Distance per person ('straight-line' distance) / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	O.47	0.47	1658	0.00
2.	PSEG4	entered	0.52	0.52	1017	0.00
3.	WDENS00	entered	0.57	0.57	822	0.00
4.	WDENS10	entered	0.59	0.58	658	0.00
5.	JRHIGH	entered	0.61	0.61	576	0.00
6.	WDENS40	entered	0.63	0.62	519	0.00
7.	PSEG5	entered	0.64	0.63	464	0.00
8.	RLY	entered	0.64	0.64	414	0.00
9.	PSEG2	entered	0.64	0.64	373	0.00
10.	MWAY	entered	0.65	0.64	337	0.00
11.	PWORKERS	entered	0.65	0.64	307	0.00

Multiple R	0.803
R Square	0.645
Adjusted R Square	0.643
Standard Error	33.433
Mean Absolute Deviation	26.6

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	103.620	9.825	0.283	3.785	10.547	0.000
JRHIGH	-29.113	2.637	-0.176	1.339	-11.039	0.000
MOTORWAY	20.553	7.771	0.043	1.385	2.645	0.008
RAILWAY	10.590	2.611	0.062	1.230	4.057	0.000
PSEG2	34.035	7.763	0.096	2.525	4.384	0.000
PSEG4	-93.888	10.792	-0.168	1.949	-8.700	0.000
PSEG5	-38.443	5.932	-0.129	2.075	-6.481	0.000
PWORKERS	25.977	10.237	0.050	2.071	2.538	0.011
WDENS00	29.477	2.212	0.240	1.703	13.328	0.000
WDENS10	20.688	2.365	0.149	1.519	8.748	0.000
WDENS40	-26.780	3.353	-0.132	1.422	-7.987	0.000
(Constant)	82.877	5.043			16.434	0.000

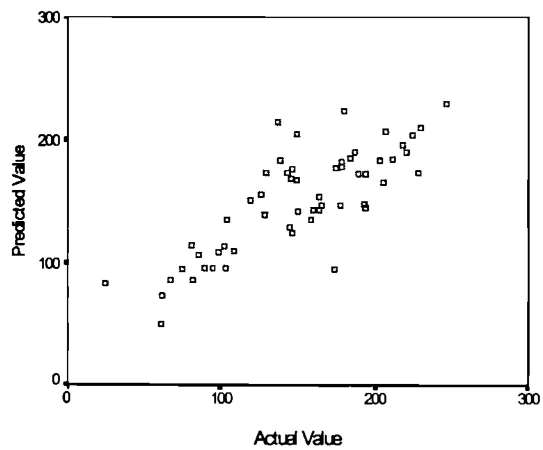


A12.1.4 Dependent Variable = Distance per person ('journey-time' distance) / Independent Variables = Land Use and Socio-Economic Variables

Stage	*Variable*	*Entered/removed*	R^2	*Adjusted* R^2	*F*	*Significance*
1.	CARSPP	entered	0.46	0.46	1596	0.00
2.	PSEG4	entered	0.51	0.51	986	0.00
3.	MOTORWAY	entered	0.54	0.54	732	0.00
4.	JRHIGH	entered	0.58	0.58	653	0.00
5.	PWORKERS	entered	0.62	0.62	609	0.00
6.	WDENS40	entered	0.65	0.65	574	0.00
7.	PSEG5	entered	0.65	0.65	505	0.00
8.	WDENS40	entered	0.66	0.66	449	0.00
9.	RAILWAY	entered	0.66	0.66	403	0.00
10.	JRBAL	entered	0.66	0.66	368	0.00
11.	WDENS30	entered	0.67	0.67	336	0.00

Multiple R	0.815
R Square	0.665
Adjusted R Square	0.663
Standard Error	29.429
Mean Absolute Deviation	23.4

Variable	*B*	*SE B*	*Beta*	*VIF*	*T*	*Sig T*
CARSPP	105.111	7.351	0.317	2.734	14.299	0.000
JRBAL	-5.805	1.636	-0.057	1.420	-3.548	0.000
JRHIGH	-43.623	2.381	-0.292	1.409	-18.318	0.000
MOTORWAY	108.919	6.768	0.251	1.356	16.094	0.000
RAILWAY	11.821	2.392	0.077	1.333	4.943	0.000
PSEG4	-105.214	9.249	-0.207	1.848	-11.376	0.000
PSEG5	-40.413	5.272	-0.150	2.116	-7.666	0.000
PWORKERS	86.511	9.046	0.185	2.087	9.564	0.000
WDENS00	-7.495	1.889	-0.067	1.602	-3.969	0.000
WDENS30	-6.686	2.653	-0.039	1.309	-2.521	0.012
WDENS40	-34.731	3.151	-0.188	1.621	-11.022	0.000
(Constant)	105.583	4.725			22.344	0.000



A12.2 Summary of Results For Regression Analyses where the Dependent Variable is Distance per Person and the Independent Variables are Socio-Economic and Land Use Characteristics

Dependent variable → *Independent variables*[1] ↓	*'Straight-line' distance per person per week*[2]	*'Journey-speed' distance per person per week*[2]	*Comments*
CARSPP	+ + +	+ + +	Travel distance increases as the level of car ownership increases.
PSEG1			Travel distance is lower in areas where there is a large proportion of households in socio-economic groups 4 and 5.
PSEG2	+ +		
PSEG3			
PSEG4	− − −	− − −	
PSEG5	− − −	− − −	
PWORKERS	+ +	+ + +	Travel distance increases as the proportion of persons in paid employment increases.
JRBAL		− −	Travel distance is consistently lower in areas where there is a high job ratio (more than 1.5 jobs per workers).
JRHIGH	− − −	− − −	
WDENS00	+ + +	− −	Travel distance is low in wards where the density is 40-50 persons per hectare.
WDENS10	+ + +		
WDENS20			
WDENS30		−	
WDENS40	− − −	− − −	
MOTORWAY	+	+ + +	Average travel distance is higher in areas that are close to the motorway network and in areas that are close to the railway network.
RAILWAY	+ +	+ +	
Sample size (number of survey areas)	56	56	

1. Refer to Appendix 11 for an explanation of the independent variables included in the regression analysis.
2. Refer to Appendix 3 for an explanation of the symbols used to indicate the strength of the relationships.